

# FEMP FIRST THURSDAY SEMIN@RS

## DOE FEMP First Thursday Seminar Learner Guide

Course ID: FEMPFTS27

Duration: 1.5 hours

Prerequisites: None

IACET CEUs: 0.2 CEU

Level: 201



## O&M Best Practices for Small-Scale PV Systems

### Course Description

This course focuses on maintenance of existing PV systems and the ability to increase predictability of operations, analyzing expected versus actual output, and reducing down time. The topics covered will help energy managers plan for critical PV O&M activities; understand the necessary qualifications for service personnel; ensure proper safety procedures during diagnostics, isolation, and repair; and realize the economic benefits of a well-maintained PV array.

### Learning Objectives for O&M Best Practices for Small-Scale PV Systems:

- Assess critical items to manage assets and plan for a complete PV O&M program
- Identify preventative maintenance practices necessary to perform on a regular basis
- Identify and diagnose corrective maintenance and repair of failed PV components
- Determine and follow proven safety procedures when repairing equipment
- Understand the professional qualifications of personnel required to perform work on PV equipment

### Instructor Biographies

#### Brad Gustafson, Federal Energy Management Program

Brad Gustafson is supervisor for the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP). In 1995, Gustafson began supporting federal energy initiatives as an employee of Lawrence Berkeley National Laboratory. While at FEMP, he has acted energy savings performance contract project facilitator, technology transfer program manager, utility program manager, federal fleet management program manager. In 2002, he served as Senate legislative advisor for Senator Lincoln Chafee. Before joining FEMP, Gustafson was program manager for the Pacific Gas and Electric (PG&E) HVAC program at the PG&E Energy Center.

### **Andy Walker, Principal Engineer, National Renewable Energy Laboratory**

Andy Walker, Ph.D., is principal engineer at the National Renewable Energy Laboratory. He conducts engineering and economic analysis of energy efficiency and renewable energy projects for the Federal Energy Management Program and other non-governmental clients and specializes in assisting various organizations to plan renewable energy projects at multiple sites. Walker also teaches energy classes. He is the author of more than 28 book chapters, journal articles, and conference papers and has been recognized with 11 awards from professional associations and government agencies. He holds Bachelor's of Science, Master's of Science, and Doctorate degrees in mechanical engineering from Colorado State University and is a registered professional engineer in Colorado.

### **Kris Sutton, Solar Energy International Instructor-Trainer, Solar Energy International**

Kris Sutton has worked full-time in the PV industry since 1999 and is a NABCEP Certified Solar PV Installer. He regularly teaches technical trainings on the design and installation of photovoltaic systems - both commercial and residential, with a heavy emphasis on safety. He has been employed as an installer, project manager, and owned his own solar consulting business working with utilities, architects, engineers, general contractors, building departments, and homeowners through all phases of the PV design and installation process. Sutton serves as Solar Energy International's Instructor-Trainer and helps develop curriculum.

### **Joe Villacci, IREC Certified Master Trainer/PV, Solar Energy International**

Joe Villacci specializes in system design, installation methods, and performance verification of solar electric systems. He works as a technical trainer and curriculum developer for Solar Energy International (SEI) and is responsible in part for development of SEI's PV training facility. Joe also provides design review, commissioning, and troubleshooting services. Joe is an IREC Certified Master Trainer/PV and NABCEP certified PV installation professional.

### **Karin Christensen, Chief, Facility Operations, National Conservation Training Center, WV**

### **John Seals, Facility Conditions Specialist, National Fish Hatchery**

### **Mike McMenamin, Facility Manager, John Heinz National Wildlife Refuge**

## **FTS 27 Course Transcript**

### **Course Introduction**

Hello. I'm Brad Gustafson, FEMP's program manager for Customer Services. I'm a professional engineer, a certified energy manager, and a LEED accredited professional, and I'll be your instructor for this First Thursday Seminar: O&M Best Practices for Small-Scale Photovoltaic Systems.

For many years, the federal government has led the way on installing PV systems. Now, with many PV systems in place, it is increasingly important to focus attention on operating and maintaining these systems for optimum power generation.

This training will focus on small-scale PV systems – 100 kW or less. But it covers many best practices that apply to systems of all sizes.

Our subject matter experts for this seminar are Andy Walker from the National Renewable Energy Laboratory, and Joe Villacci from Solar Energy International. Now, here's a brief tour of the site and how it works.

The left video box presents the main seminar content. The right video box presents supporting information. From time to time, we'll ask for your opinion and show the results here.

Use the zoom bar to change the video window size. Click on the lower right box for links to additional resources and documents to download.

Click on the lower left box for links to training resources. Links will open a new browser window. Click out of the window to return to the main screen.

Use the center box to submit questions or comments. FEMP will compile the questions and make responses available after the broadcast.

And, at the end of this seminar, please click on the link to complete a short quiz and course evaluation to receive continuing education credits. The seminar will also be archived for future on-demand viewing.

Here are the learning objectives for today's seminar:

- Assess critical items to manage assets and plan for a complete PV O&M program
- Identify preventative maintenance practices necessary to perform on a regular basis
- Identify and diagnose corrective maintenance and repair of failed PV components
- Determine and follow proven safety procedures when repairing equipment
- Understand the professional qualifications of personnel required to perform work on PV equipment

We hope this seminar will help you keep your PV system running at full capacity. Now let's get started!

## Module 1: O&M Benefits

PV systems are very reliable. With few moving parts, they can last 25 years or longer. But over time, a burnt fuse here or a cracked module there can reduce energy delivery capacity to 80 or 90% of what the system is capable of. That's why a sound PV O&M program is imperative.

It can benefit your agency in three important ways:

First: it improves performance, to increase the amount of power delivered at any given time;

Second: it reduces downtime, to maximize system availability and annual energy delivery; and

Third: it increases system lifetime, to 25 years or longer.

However, some critical questions to ask right up front are:

“Who will maintain my PV system?”

“What level of O&M is needed to ensure performance without wasting money on unnecessary measures?”

“How much should I budget for O&M?”

“How can I find funding to make major repairs if necessary?”

The answers to these questions depend on your agency, your site, and your circumstances. However, there are three good options:

One: use trained and qualified on-site maintenance staff;

Two: contract with the company that installed the system; or

Three: contract with a third-party maintenance provider.

The upside of a maintenance contract is that qualified experts come to the site, check the system, and report findings on a regular basis. If problems are found, they are corrected straight away, often under warranty. The downside is that a maintenance contract adds cost.

## **Ground Mounted at Fish and Wildlife Service National Conservation Training Center**

Now that we have a good understanding of the various options, let's visit a ground-mounted array at the U. S. Department of Interior's U.S. Fish & Wildlife Service at the National Conservation Training Center, in Shepherdstown, WV.

### **Benefits of Ground Mounted Array**

Here we are at a 47kw photovoltaic array that is powering a wastewater treatment facility for the U.S. Fish & Wildlife Service at the National Conservation Training Center, in Shepherdstown, WV.

This is a ground mounted photovoltaic system – specifically a fixed mounted rack. It does not have a tracking system and is not tilt adjustable. It is designed to be fixed in place with an average year-round tilt.

Ground mounts like this sets up a little high off the ground which is a good design for a site like this. By examining the native vegetation and mounting the modules high enough, you may not need to mow or deal with the vegetation growth under the array.

The other benefit of an elevated fixed mount is the space it creates for snow to fall mitigating build up that could interfere with system production.

Ground mounted arrays also provide ease of access for cleaning and maintenance tasks and do not require large roof mounts.

### **Audience Question:**

Here's question from our audience:

*I understand the difference between O&M for small and large systems, but what about ground mounted vs. roof mounted systems, or tracking vs. non-tracking systems?*

### **Ground-mounted vs. roof-mounted; tracking vs. non-tracking**

Kris:

When it comes to operations and maintenance there are a few variables based on where is the array. For starters let's talk about roof mounted versus ground mounted.

Ground mounted has great benefits because it's easy to access. You can drive a truck right up to it, you can park up next to it for washing modules, maintenance – any of that sort of stuff tends to be easier on a ground-mounted array.

When its roof mounted then you get into how high is the roof, what's the pitch on the roof, and can I get up there easily. You get into a much higher danger level once you're on to roof-mounted arrays. So repair work on roof arrays can be more dangerous and sometimes more costly than a ground mounted array.

Now when we start to look at ground mounts we maybe put that into two categories – either a fixed ground mount, something that's fixed in position versus a tracking ground mount something that's going to move or track. There is a much higher probability that a tracking ground mount is going to fail more often than a fixed ground mount because of the moving mechanism and the control systems that are required to move and track that array. So there's definitely going to be some maintenance issues with tracking systems that are going to differ significantly from a fixed ground mount.

Andy:

Yes in addition to the roof mounted and ground mounted issues that Kris just described, there's a third type which is covered parking or shade structures. Those have their own

operation and maintenance issues. They include things like ice and snow falling off the structure and where that falls and maintenance of those systems up above the ground entails their own challenges.

So each of these types has advantages and disadvantages – it's not easy to say that one is better than the other. And your selection might depend more on the needs and conditions at your site rather than which one costs less to maintain.

In addition to the roof access and fall protection issues that Kris brought up on roof top systems, you know just having people work on the roof can cause damage to the roof itself. So that's another issue to think about on rooftop systems.

In the early years we had a lot of trouble with tracking systems. A lot of times when we would visit a system after it had been installed a lot of the trackers would be out of position. But nowadays the reliability and the cost of the tracking systems has come down to the point where a lot of times we do recommend them and if you put out an RFP for a system probably all the proposals for a ground mounted system would come back proposing tracking. So the maintenance of those hydraulic systems or electrical systems which cause those collectors to track the sun from east to west across the sky would be another item on your maintenance to-do list.

## **Safety Issues**

Now, let's look at one of the most important areas of your O&M program: safety! - including personal protective equipment, arc flash protection, lock-out/tag-out procedures, and rooftop safety.

### **Arc-Flash Protection and Personal Protective Equipment (PPE)**

One of the most dangerous parts of a solar electric system is the electricity itself. There are a lot of concerns when working around electricity. One concern is shock hazard and the other is an arc flash or arc blast which is the result of an explosion of a fault in the system. This could be caused by something I did as an electrician or it could be a piece of equipment that fails. Either way, if an arc flash or arc blast happens when I'm standing in front of it I could be injured, burned, or killed.

So we are going to take a look at a few of the things that a technician needs in order to go into an electrical system and work safely. When talking about shock safety, the primary protection from shock is an electrically insulated glove. The primary protection in the gloves is the insulator. On the cuff of the insulator there is information about the gloves size and classification. For example, a "Class 0" glove means it is 1,000 volt AC rated which also means 1,500 volt DC rated.

There is then a leather glove that is put over the top of the insulator. The leather is a physical protection from nicks and punctures that could be caused by metal shavings, metal splinters - anything that could puncture through the rubber part of the glove.

The third part is a glove liner. You might think this third glove would be uncomfortably hot, but in reality the liner keeps the rubber off of your hands keeping your hands a little cooler. It also wicks some of the sweat off your hands. So your hands are usually better off with the liner than without it.

Though it might look bulky, a lot of times you only need to use the gloves to make a few tests so they don't have to be worn very often or very long in a project. I have enough dexterity to grab my leads, make my tests and get out of there safely.

It is important to make sure that the gloves are kept in good repair and nothing has damaged the gloves. The things to be most concerned with are scrapes, cuts or punctures in the insulation. It is easy for metal slivers or shavings to puncture through the insulation. That little sliver of metal that you can't see could be the difference between getting shocked and not getting shocked.

When it comes to arc flashes and arc blasts, the explosive potential of a service, we need to understand what to wear – does it have the ability to catch fire? So we wear flame-resistant clothing. In selecting the things you wear consider the exposure category.

Exposure categories are determined by engineers who analyze the potential fault current for the circuit. That is, how much current is available if I were to short across an electrical device – what's behind it? How big is the transformer? How big is the utility service supply? Is it a DC side or an AC side?

On the DC side which tend to be more shock hazards and on the AC side there tend to be flash or blast hazard potential because of the utility grid versus the solar array. So an engineer needs to do a shock hazard or blast analysis to tell the technician the right suit and category ratings.

What I'm wearing right now is flame resistant clothing with a flame resistant or arc flash suit. This will give a certain amount of resistance to fire if something were to come outside of the enclosure.

The other parts to this system a hood which is worn to help protect against an explosion that comes out and goes around my face shield. If I'm wearing this I'm also going to be wearing an arc flash face shield that will help protect my face in case something comes after me. It's a multi-step system here.

This is not a normal face shield that you go by at a store. This is designed specifically for an electrical arc. If you have an electrical arc, there is going to be a very intense UV exposure from the arc, and the face shield will help prevent the UV from burning your eyes, burning your retina, and burning your face. So this mask has a blast safety value and an energy impact safety value as well as the UV protection. So this will go on top of your hood, your safety glasses, and then your arc flash face shield above that.

So there are a lot of things we need to understand about the safety side of working around electrical components. The major part of that is training. Training is number one. If I don't have the proper training, I'm not authorized to go into electrical equipment to make tests and check up on things. I'm not allowed to move the lid of an electrical device unless I have the proper training and the proper personal protective equipment.

## **Lockout/Tagout**

Lockout/tagout is a method to isolate sources of power to a piece of equipment that needs to be serviced or maintained. It entails the ability to shut off and lock in the off position the source of supply of energy, in this case electricity.

The basic components of lockout/tagout are the locking devices, a padlock, and an identifying method to show that something is intentionally locked off for a reason.

First we will look at the AC/DC switch. Disconnect switches are very easy to lock off. When you shut the switch off and the switch handle is in the off position, there is a hole in the switch handle through which you can easily apply a lock. Then I have controlled the source of energy into my inverter.

While disconnects are easy to lock off, other devices can be more challenging and we'll look at a few of those next. When we get into unique switches like this inverter that has an integrated DC disconnect switch below it, how to lock it off is less intuitive. In this case, I'll shut off the switch and when it is in the off position there is a hole in the side where I can place my lock and thus lock off the DC connect.

If we look at this combiner box which is called a disconnecting combiner – it has the disconnect integrated with the combiner box. When I turn the disconnect into the off position I can reach behind the disconnect handle and push out the little red tab. I then have ability to lock the DC disconnect in the off position.

Now we are going to look at how to lock off solar modules. The module itself, or the string of modules, is probably the most challenging to lock off because it was never meant to be locked in the off position. It is more challenging to lock off my homerun wiring.

I cannot open the connectors unless I have verified that there is no current flowing in them. That is step number one. I never will walk up to an array and unplug it. I need to go shut off the load break rated disconnect switch that is mounted, in this case, near the inverter. I turned that off and current should have stopped flowing through these circuits. We need to verify that the current has stopped flowing.

So I'm going to grab my DC clamp-on amp meter. I'm going to turn it on to "Amps", set it for DC, zero out my meter, make sure everything is correct, and then I'm going to put my clamp-on meter around the wire and verify that there is no current in those conductors.

By shutting off the load break rated switch first, I protect myself and my conductors from damage. The problem could be that if there was a fault in the array, some sort of failure, you

could have a circulating current in the system in the case of a ground fault or some sort of a miss-wiring. So even though I shut it off back there, I want to verify here that there is no current flowing and everything is safe.

When it comes to locking off breakers, there are a couple of ways. If I want to lock off the AC interconnection back to the converter I turn off the breaker. I shut the lid and use the lid locking point for my lock. So one way is to shut and lock the lid but that limits access to the whole panel.

The other method is to lock single breakers in the off position using clamping devices. One device covers the breaker and is tightened and locked into place with a padlock. Another device has a setscrew to tighten the clamp around the breaker and is then locked and tagged in place.

One problem with the smaller devices, locks and tags, is that they create bulk and it is hard to shut the cabinet lid. So for outdoor enclosures you may need to turn off the breaker and lock the whole cabinet if it needs to be left in that position for a long time.

There is a lot of training required and a lot of systems that get put into place for managing lockout/tagout procedures. The guideline is set through documentation and training in conjunction with things like NFPA 70E as methods for proper lockout/tagout procedures.

What you need to look at is, does your company or your organization have a specific, written, lockout/tagout procedure or policy?

## **Rooftop Safety**

Here we are looking at an overview of safety procedures in rooftop access. We need to make sure that we are keeping our contractors or our employees as safe as possible by preparing them to deal with potential fall risks that are associated with rooftops.

There are two fundamental ways to manage fall safety. One is a guardrail or barrier or parapet wall around a flat roof and the other is a personal fall arrest system which is a combination of harnesses, lanyards, ropes, rope grab and anchorage to the roof.

One of the primary components of a fall arrest system is the harness. This harness has a waist and leg attachments and over the shoulder attachments – it's a full enclosure harness. When we are dealing with a fall arrest situation, moving around freely on roofs, we need to be attached to the backside of the harness. There is a d-ring attachment off the back of the harness and in this case we are using a shock-absorbing lanyard. The lanyard gives an attachment point to the rope, and a shock absorber in case someone were to fall on that lanyard and have an impact.

## **O&M Manuals**

Make sure your PV installer provides a full set of “as built” construction drawings from the original build-out, and keep them on hand. These drawings will show what was really built,

rather than what was planned. It's easier to troubleshoot and diagnose problems from "as built" drawings, especially if you were *not involved* with the system from the beginning.

When troubleshooting you will need to know the manufacturer's startup and shutdown procedures for the inverter.

Equipment manuals also list error codes that display when the system has a problem. Maintenance staff must be able to easily find and interpret these error codes as a first step in understanding a problem.

A good way to do this is to gather up *all* the supporting documentation for the installed equipment and organize it into an O&M binder. Include *standard calculations* in the binder to assist maintenance staff in predicting how the system *should* operate on a *given day*, considering basic changes in sunlight intensity and temperature. This will provide a quick check to monitor performance under changing conditions

You can also post simple *flow charts* and *short lists* of the main steps to maintain equipment -- like the inverter. Post these right next to the equipment.

When installation is complete, the installer is often required to provide O&M training. A good practice is to *videotape* this training as a refresher and to train *new* staff.

If you can't diagnose the problem from the O&M manuals or as built drawings, call the manufacturer. Manufacturers usually have good technicians to talk you through procedures and assist you in diagnosing a problem.

### **Manufacturer Warranties, Guarantees, Performance Measures**

When a PV system is constructed, the installer will provide the overall warranty on the system.

This warranty should cover parts and labor for the installation and should *also* carry the manufacturers' warranties *through* to the customer. For example, if the inverter fails, the installer under warranty would *replace* that inverter under the *manufacturer's* warranty.

Determine specifically what the installation warranty covers and for how long. It may be possible to individualize or customize coverage when negotiating the installation. Always check warranty "fine print" to see what is *actually* guaranteed.

The warranty might cover *availability* – that is, that the system components are operational. *Or*, it might cover the efficiency performance of each component. *Or*, it might guarantee a specific amount energy delivery.

System component *extended warranties* may be available but can be expensive, so you will need to value those against the cost.

Also, make sure warranties for component parts are specified for the condition of operation.

For example, many PV modules are not warranted for marine conditions – located near a coast.

The main components of a PV system – the modules and inverter – usually have *separate* manufacturer warranties.

*Module warranties* are often based on array performance and have 20- or 25-year diminishing power schedules that stipulate power loss over time.

Five-year *inverter warranties* were once common, but now average about 10 years, depending on the manufacturer.

Even the best of companies will resist or challenge warranty claims, so expect staff time and effort to enforce them should a problem arise.

Make sure the actions of the system installer and site technicians do not void the modules' warranty. While the array is designed for a specific weight load, this weight is distributed for environmental factors like snow. If a crew walks across the array to reach a spot, this could cause damage and void the warranty. Vandalism will void the warranty. Physical damage can occur, such as an object shattering the glass.

When it comes to inverters maintenance staff, must follow proper procedures. If there is a wiring error, for example, this could cause damage from over voltage and void the warranty. Holes drilled in the wrong locations can cause moisture damage.

Natural causes can include lightning, hail storms beyond the warranty specifications, and other uncontrollable events. Biological infestation can include animal nests and other debris that compromise performance.

When replacing a part under warranty, call the manufacturer first. Follow the proper troubleshooting process and receive authorization to return the part. The contractor will usually assist you, if the system warranty is still in effect. This will help cover the cost of both parts and labor.

### **Audience Question:**

Now it's time to take another question from our audience:

*Product and system warranties and guarantees are great, but what about the qualifications of the service providers who operate and maintain the system?*

### **Qualifications of Service Providers**

Kris:

So when we start thinking about working on or around a solar array we need to understand the site personnel and what the risks and safety issues are when we start dealing with this sort of electrical system.

So what we need to think about is what is the task that is going to be done? And it can be simple as far as someone who walks by the array or does maybe mowing or some sort of basic activity around the array, pulling weeds, that sort of thing. That's kind of one level. And then as we go deeper into it we start going, "Well who's qualified to actually do any troubleshooting, any diagnostics, any testing?"- Those sorts of things.

There's a lot of levels of kind of access control that then will have to be addressed by what the training for that given personnel is and whether, you know, they are a technician or not, whether they've been trained in solar or not. So those things have to be assessed by either the site supervisor, or the company, or whoever is in charge of that array.

One of the things that we need to understand when dealing with solar arrays is that one, solar is an electrical device and an electrical device can be very hazardous and potentially lethal depending on contact and exposure. So, am I doing a task that is going to put me in direct contact with anything electrical versus walking around and pulling weeds versus going into an enclosure?

When we start looking at troubleshooting and doing that sort of testing and diagnostics work, the exposure to electrical is pretty high. You're going to have to be opening enclosures, going in performing tests and when we go to perform those tests we need to know all the safety precautions. A lot of this comes back to training.

It's going to be the site supervisor's job to determine who is allowed to and not allowed to work on or around the solar arrays and determine that based on what your onsite training is with your crews. At what point do I let maintenance staff work on the arrays versus go out and hire a contractor to come in and deal with those sorts of things?

When we start looking at that we need to understand that solar is different than most other electrical devices. And I've had many occurrences where you can have a great electrician, the best electrician in the area, and if they don't know the solar parts specifically, they're not going to be well suited to do proper troubleshooting and diagnostics because solar is kind of a niche side of the electrical industry so training is going to be required whether it's your site staff who - maybe you have onsite electricians who do all the electrical work on site. In order for them to work on the solar array they should have custom, special training about solar specifically on how those things work so they can work safely.

If you are hiring in a contractor you really want to look at hiring in a local solar contractor or a regional solar contractor who works on these systems all the time and not just any electrician out there who doesn't have specific training.

The same goes with engineers when we start dealing with designing systems. You can have a great engineer who if they've never worked on designing solar specifically, it's unique enough system that it does require a very specific amount of training.

So the sorts of things we are trying to prevent is shocks, falls from roofs and things like arc flash and arc blast and just all the dangers that are involved with working around any solar

arrays. So be cautious about who you allow to do any sort of installation or troubleshooting work out there in the field.

Andy:

Yes, you know the PV panels are energized whenever the sun is shining so before you open a cabinet or take the cover off of a piece of equipment you'd have to be a licensed electrician – licensed within the jurisdiction that you're performing the work.

And as Kris pointed out, an electrical license isn't enough. You're required to have some special training in photovoltaic systems which are unique and different from the types of electrical systems that you'd find in a building or facility.

One of the trainings and certifications that you might require, or have as an optional selection criteria in selecting a service provider, would be a NABCEP certification which stands for North American Board of Certified Energy Professionals. That will guarantee that the individual has some specific training related to photovoltaic systems. So certainly when working on the electrical parts of the system and especially the live circuits which can't be turned off, you'd need the specialized training, specialized certification, and personal protective equipment for things such as arc flash protection that Kris mentioned.

But even for the non-electrical parts of the system there's probably some qualification or some training that's required of almost everybody involved in this system. For example, the people that are applying herbicides to control vegetation or pesticides to control insects, they might also require some special training and certification in the handling of those hazardous materials.

### **Poll #1**

Now we would like to hear from you. Please take a moment to answer the questions on your screen.

Thank you. Here are the results. Now, let's move into the next part of our seminar, which deals preventative maintenance.

## **MODULE 2: Routine Preventative Maintenance**

In the next part of our seminar, we will cover some fundamental practices for routine scheduled preventative maintenance. Topics will include how to factor in environmental conditions at your site, cleaning modules, and inverter inspections. Environmental conditions that have been found to affect O&M include: humidity, high temperatures, heavy snowfall, pollen in forested areas, bird populations, marine environments, high wind areas, diesel soot, industrial emissions, or dust caused by agriculture or a construction site nearby.

### **Vegetation Removal**

When looking at arrays and solar equipment, one of the things that happens on ground mounts is that the equipment gets growth underneath it whether it's grasses or weeds. Plants and

grasses growing underneath the array are not a problem. The problem starts when they start growing up on to the modules through the array, making shadows on the modules, or if growth starts to go into the equipment.

So in this case they are in the process of cleaning up and removing all of this vegetation. You want to kill off the vegetation at the base and remove it so it does not grow through the equipment. Certain plants and critters have a way of finding their way in to this type of equipment and we need to protect it accordingly.

## **Environmental Siting Conditions**

So here we are with the Fish and Wildlife Service National Conservation Training Center and here around and behind us is our photovoltaic arrays.

We are in the operations and maintenance part of it. It was important for us to consider the natural resource, including the habitat and natural wildlife that is in this area. So we chose this grassy field that was near our main distribution.

Its not because we are mandated, it's because it's the right thing to do, and we benefit from the ease of maintenance. For example we accentuated the arrays so they are off the ground so the base of the arrays come to about the natural height of the grasslands around it.

We only mow once a year, which minimizes the times we have to mow. We choose august for the month to do that because at that point the ground nesting birds have left the area and also other wild life like white tail deer and foxes, their young have matured and moved on as well. The other thing is that August is still early enough in the season for the grasslands to grow a small stand before the fall and winter set in, so other wildlife such as turtles can enjoy and thrive in the environment.

The other thing I want to point out too is that we only spot spray for exotic invasive around the area, instead of broadcasting for the whole area or mowing it all down to take care of thistles or other exotic vines that may grow up the poles.

## **Routine Cleaning**

When it comes to cleaning modules, the first question is, "Do I need to clean them at all?" A lot of studies are showing that it's often not worth the price and the time to clean the modules.

It comes down to, "How steep is the array?" The flatter the array is the dirtier it's going to get and the more it will hold dirt and the more often it will need cleaning. The steeper the array gets, especially past 15 degrees or so the easier rain will wash the debris off and it will not need additional cleaning.

The other question is, "How much rain do I get?" If there is a lot of rain in your area it is less likely that the array will need cleaning. The things to look for are dirt, dust, pollen, bird excrement, sap – regional issues.

If I am going to clean the module, the first thing to look at is the presence of ground faults. Check the inverter to make sure there are no faults or errors before approaching the array for cleaning.

If it's just dry dirt and dust I can use a dry brush the modules off. If I need more than that I can use water. Use a hose with a sprayer, not a pressure washer. Use water only, no soap or chemicals – in fact, using them could void the warranty.

Spray water on the modules either first thing in the morning or late in the day. Do not spray the modules with cold water when the arrays or hot or in the heat of the day. Try to wash modules either in the mornings or the evenings.

If there is dirt, grime or bird excrement that is baked on the module, a sponge or soft bristle broom or brush can be used to agitate the dirt to get it moving. Usually I spray down the module with water. Use a push broom to scrub the dirt, and then rinse it off. That's about all that is needed.

I don't want to scrape the modules with a hard metal scraper, scratch the glass. I don't need to use a squeegee – a lot of times just water, use of a push broom, and a water rinse is sufficient.

Be careful up there!

### **Inverter Power: Expected vs. Actual**

We need to confirm that your system is producing the right amount of power. The nameplate rating of our system is 8,400 watts at standard test conditions. In the real world you are not always going to see standard test conditions. So we have three factors to consider. First is our system derate factor, second our irradiance factor, and third our temperature factor.

To calculate our system derate factor for this array we are going to look at soiling and we're going to estimate a 1 percent loss for the dust on the array. We're also going to consider a 1 percent voltage drop in our system up to our inverter. And we've looked up the CEC rated efficiency of the unit and found it to be 96 percent efficient.

When you multiply these variables together we find that our system derate factor is .94.

Next we are going to look at our irradiance factor. To calculate or measure the irradiance you need to use a pyranometer. Let's walk around to the array and take a measurement.

To measure the irradiance, make sure that the calibrated cell of the irradiance meter is in the same plane as the array. We are getting 800 watts per meter square. So let's put that into our calculation.

Our measured irradiance was 800 watts per meter square and our standard test condition irradiance is 1,000 watts per meter square. That gives us a .8 irradiance factor.

We are going to use an infrared thermometer to test the cell temperature of our module. The back sheet of the module is the most accurate place to do this. We are reading 55 degrees Celsius.

Now that we know the measured cell temperature of our module, the other thing we need to account for is the temperature coefficient of power. We look on the spec sheet and find that this module has a negative .4 percent temperature coefficient of power. That means if the temperature is above standard test conditions we are going to lose power, and if we are below the 25-degree standard test condition then we can gain a little power.

In this case we found that our cell temperature was 30 degrees above standard test condition so we are going to lose a little power due to the high temperature that the array is operating at.

Once you run through your calculations you find that you have a .88 temperature factor. To then figure out the total derate factor on the nameplate of the system, we multiply our system derate factor of .94 times our irradiance factor of .8, times our temperature factor of .88. Let's see what we get.

Now we can calculate our total derate factor. We will take into account our system derate factor of .94, multiply by our irradiance factor of .8, and multiply that by our temperature factor of .88 and that gives us a .66 total derate factor.

Now we need to apply that derate factor to the STC nameplate rating of our system which is 8,400 watts. We multiply that times .66, which equals 5,544 watts. So this system should be producing about 5,544 watts. Let's go check and see what it is doing.

I'm reading 5,450 watts, which is within tolerance. So it seems that this system is performing as expected.

## **Inverter Inspection**

When it comes to maintaining inverters one of the few things that has to be done regularly and checked is the ventilation fans for the inverter's cooling system and whether the intake screens are free of debris.

We're going to take a minute and look at this inverter's cooling system and see how the air flows through the unit – where the intake and exhaust air move through and how to make sure it's a clean fan system.

In this case the inverter manual tells me to shut off the AC and DC disconnect switches and then wait for five minutes for the internal capacitors to discharge before opening up the fan housing. So we shut off the AC disconnect and the DC disconnect and then we'll wait for five minutes and then open the fan enclosure.

So now we'll look at this inverter and how to remove the screen on the fan and check it for debris. This unit has a fan on each side so you would repeat this process for each fan.

In this case I'm taking a small flat-head screwdriver to leverage a little piece and remove the screen for the intake air. The manufacturer recommends a few acceptable ways to clean the screen. You can use compressed air and blow it out, you can use a little brush and scrub it out, or you can use a shop-vac to remove any debris or buildup.

This inverter also allows us to remove and check the fan. Remove the fan from its housing, disconnect the little wire harness and pull the fan out. Make sure there is nothing caught in the fan – that there's no debris – and that the fan blade is rotating, as it should. Then reinstall the fan and get the system back on line.

Each inverter will have a slightly different procedure on this cleaning process so always check the manual for the best process to follow for checking the fans.

We just looked at the intake ventilation on the inverter. The intake air comes from the bottom, blows the air through the back of the inverter's chassis and then the outtake air comes out through the side fin. So in addition to the intake fan, be sure to remove the cover screen and make sure that the outside exhaust is not clogged with anything.

So we have a fresh air intake and an outtake and there is no debris built up inside.

Every inverter is different and the vents and fans will be checked differently. This inverter has a removable screen. All you need to do is pop that out and make sure that it is clean and free of debris. You can use a shop-vac or a little brush to make sure it is clean and then put it back in.

Some inverters may have multiple screens – so again, always consult the manual for the appropriate process.

There are many inverters that do not have integrated fans and vents. This inverter has a heat sink on the front of it that dissipates the electronics' heat through air movement across the fins. So for an inverter like this all you need to do is check the fins. Make sure there is no debris, buildup, bird or wasp excrement, inside there – that the fins are clean and clear.

Every inverter on the market has slight differences when it comes to how to maintain and check the fans and the ventilation system. So always check the manufacturer's operating manual for the proper procedure to work on that inverter.

### **Audience Question:**

Now that we have covered routine maintenance, let's take another question.

*What does it mean when you hear inverters making a loud humming noise or if they get really hot?*

### **Inverter Noises and Humming & Overheating**

Kris:

Another consideration is when the inverter's making power that fan noise may change through

the course of the day. In the morning when it's cool out or on a cold winter day the inverter may be making almost no noise and still making power. The fans often will ramp up and down in an inverter based on the heat inside the unit.

So if it's not very hot in there or there's not very much power going through it, the fan may be off. And the fan will go up and down based on the ambient air temperature and how many watts the unit's processing.

Now there's going to be a spot where you're taking internal air and external air, basically throughput air, so there's going to be a place on the unit where hot air is coming out – that's the exhaust air. So you are going to have spots on the inverter where it's hotter than other spots based on that exhaust air coming out.

The other thing to consider is some inverters don't have fans – some inverters use a heat sync. So there's a metal thin set that dissipates heat through ambient air temperature with a heat sync. If you touch that, especially on a hot day with full sun, that's going to be very hot to the touch and it's supposed to be – that's the purpose of it. It is dissipating heat through the heat sync and that thing may be even hard to put your hand on because it's hot to the touch.

So just be aware that the audible level will vary based on how many watts are going through it so midday it could be louder and in the morning or end of day it could be quieter. And the fan level will move with that as well or the physical temperature of the unit will change based on all that power dissipation.

So that's a normal condition. If you look at the inverter and it's hot to the touch but the lights are on and it's green, and everything is happy, and there are no errors and it's making electricity, that's what it's meant to do.

If it overheats it is going to throttle back the array. It's going to reduce the output of the array in order to thermally manage the inverter. And so it will throttle down and it will back off on the amount of solar it lets through if it has to. Or, if it was a problem, it would shut down all together and just shut itself off and probably flag an error. So unless there's an error on there it's probably fine to have varying levels of sound and heat coming off your inverter.

## Poll #2

Now we would like to hear from you. Please take a moment to answer the questions on your screen.

Thank you. Here are the results. Now, let's move into the next part of our seminar, which deals preventative maintenance.

## Module 3: Corrective Maintenance

The corrective maintenance items we will review in this part of our seminar are among the most typical you will find in small-scale applications. Many of these procedures can easily be handled by qualified in-house personnel. They include diagnostics and testing, inverter

trouble-shooting, and examples of emergency shutdown procedures at the module and grid levels.

## Fuse Checks

While performing operations and maintenance work, you may have to isolate an individual source circuit of the system. So now we are going to go over how to safely perform that operation. First off, you want to make sure you have your proper PPE on, based on the fault hazard that is available. You also want consider that if the system is turn on its going to be under load, so there will be current flowing in all of the circuits.

To safely lift a fuse holder, you are going to want to make sure there is no current flow, and to do that were going to turn the whole system off

So now that we have our system turned off, we still want to confirm the there is no current flow, because there may be a fault of some kind we don't know about

The big difference you see here between this and a circuit breaker is that these are touch safe fuse holders, there are not actually load break rated like a circuit breaker is. So if I go on and open this thing up under load, it could have a really dangerous arc there that could set this box on fire and hurt whoever is working on it. So I want to be sure to identify this as a touch safe fuse holder, so I know that I have to confirm and double check to make sure that there is no current flowing in the system.

I am going to use my clamp on meter to verify that there is no current flowing through the system. Now, the typical meter you may find at your local hardware store may only be rated for AC. This one is rated for both AC and DC, so you want to make sure you have the right Clamp On Meter since we are testing DC.

I am going to set it to AMPs, and I will want to zero out the meter and make sure it's on DC

So I've verified that there is no current flowing in the system, I can safely lift my fuse holders, and now I have isolated each circuit in the system.

## DC System Voltage and Polarity Checks

So we need to confirm we have the correct voltage and polarity in the system. So the polarity test is pretty unique to the DC side of our system, On the AC side the polarity is changing 60 times per second, while on the DC side you have a fixed polarity. If you wire that wrong, you can have a situation where you have increased voltage and that can damage the components of the system and be a hazard.

We are going to go ahead and test for the correct voltage. We need to also understand that our system is in an open circuit condition, so we can expect to see a VOC voltage from our array. If we were in an operating condition we would see a volts maximum power or a VMP condition from our array, which will result in a lower voltage. So it is important to know what you expect to see before you run the test.

We know that the array is warmer than usual; it is very hot right now so we are going to see below an STC VOC. We want to make sure that our black lead plugged into our common goes to the negative on our circuit, which we have here our black lead going into our negative bus bar. Our positive lead, we do not want to run that to our positive bus bar, we want to run the positive, the red wire, right to the individual circuit.

In circuit one we see 393, which is within tolerance of what we expected, circuit two also has the correct polarity and it is at 392, and circuit three has the correct polarity and it is at 395.

Now, if we had the reverse polarity, you would see a little negative symbol show up before the number. So it is really important to look at that while you are running these tests.

### Checking Current on Source and Output Circuits

So now we are going to verify that our system is operating correctly on the DC side, we want to confirm that the correct amount of current is running through the circuits. The inverter should be maximum power point tracking, so we should see the IMP value from the circuit, so that is what we are going to be looking for. Each circuit is mounted at the same tilt and orientation so the current should be the same for each one of them.

Now the amount of current that is flowing is directly related to the amount of irradiance that's on the array right now. So we are going to have to use our pyranometer, or irradiance meter, to measure the amount of irradiance that is on the array, and then we are going to use our DC Clamp On Meter to measure the current in the wire.

Next we are going to use the irradiance meter to measure the amount of irradiance on the array. Make sure to have the calibrated cell of the unit on the same plane as the module. I find that this array is receiving 875 Watts per meter squared.

So before we even open up the combiner box we are going to want an expectation of the current we will see on each circuit. So we looked at a spec sheet for our module and found that the IMP value is 7.78 amps, but that's at standard test conditions. When we measured irradiance we found 875 Watts per meter square, which give us an irradiance factor of .875.

So I take me 7.78 amps as my IMP and multiply that by my irradiance factor of .875 and that gives me an expected value of 6.8 amps for each source circuit that I am about to measure.

Now, the output circuit would be from the three source circuits that are in parallel in this box, when they come together in parallel, they come to 23.34 amps at standard test conditions. But we are not at standard test conditions, we measure 875 watts per meter squared, which is an irradiance factor of .875. So you multiply 23.34 by .875 and that give you 20.4 amp as your expected value on the PV output circuit. ‘

So lets open up this box and confirm the expected values.

This test needs to be done with the system in operation. So I can't open up the DC circuit, I need to leave the system operating, so I need to defeat the handle to open up the box while

the system is still in operation. So again, you want to make sure you have the proper PPE on before you run this test. We're going to look at our source circuits. We're going to make sure we have our DC clamp meter, we set it to amps, we zero it out before our measurement.

So all of the strings are measuring about 7 amps, which is normal. What we are seeing is what we expected from the system, so the system seems to be operating at maximum power.

Now we are going to look at the output of the system. Since we know that there are three source circuits in parallel, and we are at 875 watts per meter squared, we should see about 20.4 amp for the output of this system. So again, we are going to get our meter set properly. I like to test both the positive and the negative, because they are pretty easy to get to, and it's a good way to tell if you have a problem in your system. The current on the positive and negative should be equal, and if not you might have a problem, you might have a fault of some kind. Here everything was equal so it seems like the system is performing correctly.

### **Ground Fault Troubleshooting**

One of the biggest hazards with the operation of a PV system is a Ground Fault. In normal operation the current flows between the positive and negative, but in the case of a ground fault, normally not energized components can become energized which then becomes a hazard. So think of it like this, if you have a module with one of the wires coming off of it that's pinched between the metal racking and the module, that can make it that the current decides to flow on the metal racking on the system, rather than the positive and the negative wire.

A ground fault also can be caused by expansion and contraction issues in the system, which can be caused by wires expanding and contraction over a rough edge on the conduit fitting before it comes into the box – lots of different issues that can cause a ground fault.

Per national electric code the inverter that we are using should be UL-listed, and it must be able to provide ground fault protection. What that actually means is that the inverter must be capable of detecting the ground fault, and in the event of a ground fault it will open up the circuit. That won't completely get rid of the hazard but it will mitigate the hazard. The other thing the inverter needs to do is provide indication of the fault. So if you see here if you look a little but closer, you can see that this inverter is showing a red light, which indicates that a ground fault may be present on this system. So if I walk up to a system and I see a light like this, I'm sure not to make any physical contact with any of the metal on the system before I put on the appropriate PPE.

Now trouble shooting a ground fault like this and finding it to identify and isolate the circuits it's on. That will require certain training and experience. Typically the way that we do this is with a digital multi-meter to find certain ground faults, or you might have to run an insulation resistance test. But to do any of this safely you need to make sure you get the further training and experience to safely take this on.

## Inverter Service Procedures

So we are standing behind the array here and we are looking at what we would call the balance of systems, the rest of the equipment rather than the solar. So the solar array wiring is coming down from the display into the DC disconnect wiring switch here. This DC disconnect switch is the way we can isolate the solar array from the inverter on the DC side for service and maintenance. So the wiring is going to come down from the array, into the switch, through the disconnect, into the inverter itself

So now, this is the inverter, this is what is turning the DC electricity from the solar array into AC electricity and synchronizing that power with the utility grid in order to export that power out into the grid itself. So once we turn DC in to AC in the inverter, we leave through an AC disconnect switch and that gives us the ability to isolate the AC or the grid side of the connection to this inverter. If we leave that switch on we can go over to the main utility where it connect to the grid itself.

If I need to do maintenance on this system from a technician stand point, I can walk up and turn off the AC and DC switches and isolate this piece of electronics for service, maintenance, check ups, anything I would need to do, for instance replace the inverter, I could turn off both power sources and replace the inverter, then turn it back on and get it back online.

## Emergency Shutdown – Module Level

If there is ever some kind of emergency, and you have to shut down the system as fast as you can, what you are looking for is things like breakers and disconnect switches. Disconnect switches with handles like these are called a low break rated switch, which means I can throw that switch in the off position, and shut down the DC end of the converter. I can shut of the AC switch as well and shut off the AC side of the converter. When this AC switch goes back to the building it's going to go to a breaker back in the building, and I could shut that breaker there and shut down the current going to here.

So what you are looking for are things that you can safely isolate as quickly as possible, like disconnect switches and breakers at the service panel.

So talking about emergency disconnects, while I said the things you can turn off are the disconnects and breakers, what you CANNOT DO in an emergency is that you do not want to come up to a plug connector and unplug that. These connectors, if there is power flowing through those connectors you are not allowed to pull these apart. So what you do not want to do is walk up and pull any connector apart and do not pull any fuses out of the circuit. Pulling fuses out, or pulling connectors apart can create a greater hazard than throwing the disconnect switches themselves.

Just to reiterate, breakers and disconnect switches are okay to throw if there is an emergency. Fuses and plug connectors do not unplug in an emergency because that can create a greater hazard potentially.

## Emergency Shutdown – Grid Level

At this particular site we have multiple converters, each of the inverters has its own AC output that need to be combined together so that they can feed into the utility itself. Behind me is an AC breaker panel, that's taking the output of each inverter and paralleling them into the AC network.

So when I look at these breakers behind me I see inverter 1, inverter 2, inverter 3, inverter 4, and they are feeding into the AC bussing. We also have a main AC breaker here down at the bottom, which connects this whole service back to the utility. Then there is a lightening or surge protector off to the side in here as well.

It's very common when we have a multi inverter site like this to have a panel that will be very similar to this in some way, to take the multiple inverter outputs and connect them all together and feed them all together back to the main point of connection with the utility grid itself.

### Poll #3

Now we would like to hear from you. Please take a moment to answer the questions on your screen.

Thank you. Here are the results. Now, let's move into the next part of our seminar, which deals preventative maintenance.

## Module 4: Calculating Savings and Public Outreach

Finally, we will cover some important steps to ensure the accuracy of metering and reporting, as well as outreach to staff, building occupants, and the public to showcase the energy, environmental, and cost benefits of your PV system.

Before we discuss typical O&M maintenance costs and how to calculate savings resulting from PV systems, here are a few main options to fund a small-scale solar energy project at your site. They include Congressional Appropriations, Utility Energy Service Contracts (UESC), Energy Savings Performance Contracts (ESPC), and ESPC Enable. ESPC Enable provides a streamlined way to incorporate small-scale PV into your energy improvement projects.

After obtaining funding to install the system, the cost of maintaining it is very low compared to O&M costs of traditional electricity technologies.

As you can see here, maintenance on the inverter, the PV arrays, and cleaning and removal of vegetation make up the majority of O&M cost. Plan to budget an estimated \$10 to \$30 per kilowatt per year, depending on the size of your system.

## Emergency Funding/ Contingency Funding for Repairs

Even with a sound O&M plan, unforeseen failures and equipment repairs may occur. Check

with your site, your regional office, or your headquarters officials to determine the best options to obtain contingency funds or emergency repair funding to keep your system operating.

A system that is down cannot save money for the agency, so calculate and emphasize the cost of downtime when requesting contingency funds.

Mike:

My name is Mike McMenamin. I'm with the US Fish and Wildlife Service at the John Heinz National Wildlife Refuge and I'm the Facility Manager here.

We have a 47-kilowatt system here at the John Heinz national wildlife refuge. Before the system was installed, you can see that we were averaging approximately 600 dollars in utility bills per month, and after the system was installed, we noticed that it dropped to about 50 dollars per month

Narrator:

With an understanding of renewable energy generation as part of a utility bill, let's calculate the amount of money your system is saving. We'll show how to project what your bill *would have been* without the system in place and, thereby, calculate the savings that result directly from the PV panels. The best way to estimate savings is to calculate the utility bill both with and without the PV. This can be a complicated calculation so fortunately most utilities will perform this calculation for you.

To correctly calculate PV cost savings, it is important to know the building's electric load profile before the PV installation and how the PV system output affects the building load profile.

Many utilities have charges that vary with time of day and seasonally, and utilities charge a demand power factor in addition to charging for energy. The only way to calculate actual cost savings due to the PV system is to analyze and compare the utility bill costs both with and without solar power. The utility bill estimated without solar, minus the bill amount with solar, will accurately show the savings, which is the difference between the two.

Brad:

Agencies should report on the benefits of PV systems to site staff, building occupants, and the general public. Many sites have developed public dashboards that can be located in public areas or made available on computer networks. These public dashboards feature user-friendly metrics and graphics for easy access.

Mike:

This is our newly installed solar display, it's really a to the visitor center and the wildlife refuge. Last year our visitation was over 150,000 visitors to the refuge.

The information that the display is trying to get across to people is that not only showing the location of the solar panels on the visitor panel, it also shows you what a solar panel looks like,

it also talks about the amount of solar panels it has on the top, we have a 4,800 watt solar system on the top of this building.

Our monitor here shows the amount of kilowatts, and you can see on a day like today we are averaging about 32 kilowatts.

Brad:

Thank you for joining us for this First Thursday Seminar. FEMP would like to thank the U. S. Department of Interior's Fish and Wildlife Service for its assistance in developing this First Thursday Seminar.

Please click on the link on your screen and take a moment to complete the quiz and short course evaluation. This will provide *you* with continuing education credits and provide *FEMP* with valuable feedback to continue to improve its training offerings.

Check the FEMP website for updates on First Thursday Seminars and new training offerings. Thank you for joining us.

## Resources for Further Study

Ground Mount PV Racking Systems

<http://solarprofessional.com/articles/products-equipment/racking/ground-mount-pv-racking-systems>

PV Ground Mounting

<http://www.homepower.com/articles/solar-electricity/design-installation/pv-ground-mounting>

Utility Scale PV Ground-Mounted Racking Solutions

<http://solarprofessional.com/articles/design-installation/utility-scale-pv-ground-mount-racking-solutions>

Ground Mounted PV

<http://solarprofessional.com/articles/design-installation/ground-mounted-pv>

Personal Protective Equipment: Insulating Gloves and Sleeves

[https://www.osha.gov/SLTC/etools/electric\\_power/ppe\\_insulatinggloves\\_sleeves.html](https://www.osha.gov/SLTC/etools/electric_power/ppe_insulatinggloves_sleeves.html)

Standard for Electrical Safety in the Workplace

<http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=70e>

OSHA Lockout/Tagout Factsheet

[https://www.osha.gov/OshDoc/data\\_General\\_Facts/factsheet-lockout-tagout.pdf](https://www.osha.gov/OshDoc/data_General_Facts/factsheet-lockout-tagout.pdf)

Control of Hazardous Energy (Lockout/Tagout)

<https://www.osha.gov/SLTC/controlhazardousenergy/>

NFPA 70E: Lockout/Tagout Guide

<http://www.ibewlocal702.org/uploads/news/Lock%20Out%20Tag%20Out%20Guide%20NECA.pdf>

Personal Fall Arrest Systems

[https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=9730](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9730)

Fall Protection Systems Criteria and Practices

<https://www.osha.gov/doc/outreachtraining/htmlfiles/subpartm.html>

Fall Protection Systems

<http://solarprofessional.com/articles/design-installation/fall-protection-systems>

Solar Farm Grounds Management Vegetation Control

<http://www.abakus-solar.us/blog/solar-farm-pv-power-plant-grounds-management-vegetation-control/>

Overview of Opportunities for Co-Location of Solar Energy Technologies and Vegetation

<http://www.nrel.gov/docs/fy14osti/60240.pdf>

Unfortunate Solar Installation of the Month: Utility Scale Edition

<http://www.greentechmedia.com/articles/read/Update-Unfortunate-Solar-Installation-of-the-Month-Utility-Scale-Edition>

Successful PV Site Evaluation

<http://www.homepower.com/articles/solar-electricity/design-installation/successful-pv-site-evaluation>

Pump Up the Power: Getting More from your Grid-Tied PV System

<http://www.homepower.com/articles/solar-electricity/design-installation/pump-power>

Do You Wash Your Solar Modules Often Enough?

<http://www.greentechmedia.com/articles/read/do-you-wash-your-solar-modules-often-enough>

PV System Energy Performance Evaluations

<http://solarprofessional.com/articles/operations-maintenance/pv-system-energy-performance-evaluations>

Safety Considerations for Live Measurements: Keep your Eyes on the Job at Hand:

<http://www.fluke.com/fluke/uses/comunidad/fluke-news-plus/articlecategories/electrical/livesafetymeasurements.htm>

ABCs of DMMs

<http://www.fluke.com/fluke/sngen/Community/fluke-news-plus/ArticleCategories/Safety/DMM-ABCs.htm>

The New NEC 690.16(B) Fuse-Servicing Requirements and Combiner Boxes

<http://solarprofessional.com/articles/design-installation/the-new-nec-69016b-fuse-servicing-requirements-and-combiner-boxes>

The Circuit-Methods: Testing and Verifying Module Voltage and Current... Prior to Installation

<http://www.homepower.com/circuit-methods-testing>

Grid-Tied PV System Performance Factors

<http://www.homepower.com/articles/solar-electricity/equipment-products/grid-tied-pv-system-performance-factors>

PV System Ground Faults

<http://solarprofessional.com/articles/operations-maintenance/pv-system-ground-faults>

PV System Operations and Maintenance

<http://www.solarabcs.org/about/publications/reports/operations-maintenance/pdfs/SolarABCs-35-2013.pdf>

Distributed Inverter Design

<http://solarprofessional.com/articles/design-installation/distributed-inverter-design>

Salem Community College Energy Institute

<http://www.salemcc.edu/energyinstitute/>

## Glossary: Photovoltaic Operations and Maintenance Key Term Definitions

**Asset Management:** a systematic process of planning, operating, maintaining, upgrading and replacing assets cost effectively with minimum risk and at the expected levels of service over the assets' lifecycle; it therefore contains all of O&M. Business services operations such as billings and collections from PPA and leased based systems customers do fall within asset management, but are not typically part of O&M.

**Administration of Operations:** Ensures effective implementation and control of operation and maintenance activities including archive as-built drawings, equipment inventories, owners and operating manuals, and warranties. Includes keeping records of performance and O&M measures provided, preparing scopes of work and selection criteria for service providers, contracting with suppliers and service providers, preparing budget, and securing funding and contingency plans for O&M activities.

**Conduct of Operations:** Ensures efficient, safe, and reliable process operations including economic NPV/ROI cost benefit financial decision support. Includes serving as a point of contact for personnel regarding operation of PV system, coordinating with others regarding system operation and any required shutdown, and providing instructions regarding defined work tasks scheduled in the morning or evening hours to avoid production losses, electrical hazards, heat stress, and local access. In addition, includes providing instructions regarding access routes, storage and lay-down areas, and hours when work can be conducted without affecting the mission of the facility.

**Provisions and Directions for the Performance of Work:** Ensures that maintenance is performed safely and efficiently including the formalization and enforcement of safety policy (including training for DC&AC safety, rooftop safety, minimum manning requirements, arc flash, lock-out tag-out, etc.). Also includes compliance with any environmental or facility-level policies regarding handling controlled materials such as solvents, weed-killer and insecticide.

**Evaluation and Provision of Sufficient Equipment Status Control:** Ensures effective equipment monitoring and analytics to remain cognizant of status. Includes comparing results of system monitoring to benchmark expectation and providing reports to facility stakeholders.

**Design and Maintenance of Operator Knowledge, Protocols, and Documentation:** Ensures that operator knowledge, training, and performance will support safe and reliable plant operation. Includes confirming and enforcing qualifications of service providers.

**Administration of Maintenance:** Ensures effective implementation, control and documentation of maintenance activities and results. Administration includes establishing budgets and securing funds for preventive maintenance, establishing reserves or lines of credit for corrective maintenance, planning activities to avoid conflict with system operation or operations at the customer site, correspondence with customers, selection and contracting with service suppliers and equipment manufacturers, record keeping, enforcement of warranties, providing feedback to designers of new systems, and reporting on system performance and the efficacy of the O&M program.

**Preventative Maintenance:** Scheduling and frequency of preventative maintenance is set by the operations function and is influenced by a number of factors, such as: equipment type, environmental conditions (marine, snow, pollen, humidity, dust, etc.) of the site, and warranty terms. Scheduled maintenance is often carried out at intervals to conform to the manufacturer recommendations as required by the equipment warranties.

**Corrective Maintenance:** Required to repair damage or replace failed components. It is possible to perform some corrective maintenance such as inverter resets or communications resets remotely; also, less urgent corrective maintenance tasks can be combined with scheduled, preventative maintenance tasks.

**PV O&M Asset Management Service Descriptions**

ACTIVITY AREA	COMPONENT	DESCRIPTION	INTERVAL	SERVICE PROVIDER
Management	Asset Management	Daily Operations and Performance Monitoring	Ongoing	Admin Asst
Management	Asset Management	Monitor alarms and site-specific alert parameters	As needed	Journeyman Electrician
Management	Asset Management	Manage inventory of spare parts	As needed	Journeyman Electrician
Management	Documents	Document all O&M activities in a workbook available to all service personnel.	Ongoing	Admin Asst
Management	Documents	Confirm availability and take any measures to secure operating instructions, warranties and performance guarantees, and other project documentation.	Monthly	Admin Asst
Management	Documents	Review O&M agreements and ensure that services are actually provided	As needed	Admin Asst
Management	Documents	Update record with preventative maintenance activities and track any problems or warranty issues and secure the record on-site.	Ongoing	Admin Asst
Management	Documents	Meet with key site staff to continue awareness, question any issues, and report on findings.	Annual	Inspection
Management	Meter	Maintain a log of cumulative power delivery (kWh to date) and chart this value against date. Chart the value even for uneven or infrequent intervals. Explain variation by season or weather.	Monthly	Admin Asst
Management	System	Compare actual output or savings to output predicted under the conditions. Solar Today magazine publishes a map with the previous months output as indicated by processed satellite data regarding the solar resource across the country, or an estimate may be derived from local measurements.	Monthly	Admin Asst

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**PV Operations & Maintenance - Service Qualifications**

Many PV O&M tasks require specialized knowledge. Typical building maintenance companies are not suitable for the requirements of successful PV asset O&M because the average industrial technician is not familiar with DC wiring and components, power conditioning equipment, and the uncontrollable and intermittent nature of the resource and resulting power generation.

Specialized training of third-party maintenance personnel is necessary, as is awareness on the part of the building owner and utility staff, to provide effective O&M while ensuring safety. The qualifications of each job category depend on the requirements of the job and are listed for labor; technician; electrician; designer; roofer.

NABCEP refers to North American Board of Certified Electricity Practitioners certification.

Service Categories and Associated Qualifications:

Service Category	Scope of Work	Qualifications
Administrative Assistant	Record-keeping, service confirmation, correspondence	Excellent interpersonal and communication skills (written and verbal). Diligent record keeping. 2 to 5 years of experience. Excellent MS Office and computer skills.
Designer	Specifications, drawings, modeling and analysis, codes and standards.	B.S. in EE (4-year engineering degree); registered PE licensed to practice engineering in the jurisdiction; NABCEP PV Installer Certification; CAD (AutoCAD) and graphics skills; knowledge of IEEE, NEC, NESC, and other codes and standards for PV systems; required level of errors and omissions insurance.
Module Cleaning	Cleaning PV Arrays	10 OSHA Card; Required level of bonding and insurance; drivers license and reliable transportation; minimum 18 years old.
Tree Trimming	Removal of vegetation	50 OSHA Card; drivers license and reliable transportation; required level of insurance; minimum 18 years old; any required training or license for herbicide application.
Pest Control	Nesting vermin removal, Nesting vermin prevention	10 OSHA Card; safety training in handling animals and detritus; required level of bonding and insurance; drivers license and reliable transportation; minimum 18 years old; most states require license for pesticide
Roofing	Roof leak repair, roof tile repair, re-roof	Roofing contractor's license for the jurisdiction; 10 OSHA Card; safety training in fall protection equipment and use (or 50 OSHA Card); required level of bonding and insurance. 2 to 5 years of experience.
Structural Engineer	Foundations and rack inspection/design	B.S. CE (4-year engineering degree); registered PE licensed to practice engineering in the jurisdiction.
Mechanic	Maintenance and repair/replace of tracking mount components	50 OSHA Card; 2 to 5 years of experience; required level of bonding and insurance.
Master Electrician	Module replacement, inverter replacement, fuse/breaker replacement, conduit routing, wiring, ground fault repair	Electrical Contractor's license for the jurisdictions; 50 OSHA Card; NABCEP PV Installer certification; experience in the design of medium voltage electrical systems. 5+ years experience with PV systems; color vision. Certification by the North American Energy Reliability Corporation (NERC) is necessary for positions that affect the power grid.

Service Category	Scope of Work	Qualifications
Journeyman Electrician	Module replacement, Inverter replacement, fuse/breaker replacement, conduit routing, wiring, ground fault repair	50 OSHA Card; training in arc-flash, lock-out/tag-out, and other special protective equipment and procedures; NABCEP PV Installer certification; experience in the design of medium voltage electrical systems. 5+ years experience with PV systems; color vision.
Network/IT	Internet/network repair, monitoring equipment repair	Knowledge of specific monitoring devices (training by system supplier) and how monitoring system is connected through network connections or wireless or cellular modem; knowledge of Modbus, DNP3 and other protocols, HMI operator interfaces; 2 to 5 years of experience. Locus, Enphase, Itron, etc. monitoring device knowledge.
Inspection	Diagnostic analysis; visual inspection, specific testing,	Diagnostic analysis; NABCEP PV Installer Certification; 2 to 5 years of experience.
Inverter Specialist	Inverter repair, upgrades	Skills to perform maintenance, diagnostics and repair for inverter: factory trained and certified; 5+ years experience.
PV module/ Array Specialist	Module repair	Skills to operate, troubleshoot, maintain, and repair photovoltaic equipment: NABCEP PV Installer certification. 2 to 5 years of experience.
Utilities locator	Locate underground utilities.	2 to 5 years of experience.

**PV Preventative Maintenance - Service Descriptions**

Preventative maintenance is required to maximize system output and to take measures to prevent more expensive failures from occurring. Conduct preventative maintenance work early in the morning or late in the evening to avoid heat stress, minimize electrical hazards, and minimize production losses.

This is broken out into five activity areas: Inspection, Service, Testing, Cleaning and Emergency Response

ACTIVITY AREA	COMPONENT	DESCRIPTION	INTERVAL	SERVICE PROVIDER
Cleaning	PV Module	Clean PV modules with plain water or mild dishwashing detergent. Do not use brushes, any types of solvents, abrasives, or harsh detergents.	Annual	Module Cleaning
Emergency Response	System	Contractor available by email and phone 24x7x365	Ongoing	Journeyman Electrician
Inspection	AC Wiring	Inspect electrical boxes for corrosion or intrusion of water or insects. Seal boxes if required.	Annual	Electrician
Inspection	AC Wiring	Check position of disconnect switches and breakers.	Annual	Electrician
Inspection	AC Wiring	Exercise operation of all protection devices.	Annual	Electrician
Inspection	DC Wiring	Test system grounding with "megger"	Annual	Journeyman Electrician
Inspection	DC Wiring	Scan combiner boxes with Infrared camera to identify loose or broken connections	Annual	Journeyman Electrician
Inspection	DC Wiring	Inspect cabling for signs of cracks, defects, pulling out of connections; overheating, arcing, short or open circuits, ground faults.	Annual	Electrician
Inspection	DC Wiring	Check proper position of DC disconnect switches.	Annual	Electrician
Inspection	DC Wiring	Inspect and maintain the wiring and condition of wire insulation and protective materials.	Annual	Electrician
Inspection	DC Wiring	Open each combiner box and check that no fuses have blown and that all electrical connections are tight. Use an infrared camera for identifying loose connections because they are warmer than good connections when passing current.	Annual	Electrician

ACTIVITY AREA	COMPONENT	DESCRIPTION	INTERVAL	SERVICE PROVIDER
Inspection	DC Wiring	Look for any signs of intrusion by pests such as insects and rodents. Remove any nests from electrical boxes (junction boxes, pull boxes, combiner boxes) or around the array. Use safe sanitation practices because pests may carry disease.	Annual	Vermin Removal
Inspection	Inverter	Observe instantaneous operational indicators on the faceplate of the inverter to ensure that the amount of power being generated is typical of the conditions. Compare current readings with diagnostic benchmark.	Monthly	Inspection
Inspection	Monitoring	Spot-check monitoring instruments (pyranometer, etc) with hand-held instruments to ensure that they are operational and within specifications.	Annual	PV Module/Array Specialist
Inspection	PV Array	Test open circuit voltage of series strings of modules	Annual	Journeyman Electrician
Inspection	PV Array	Check all hardware for signs of corrosion, and remove rust and re-paint if necessary.	Annual	Mechanic
Inspection	PV Array	Check tightness of mounting clamps. Re-install any modules that have become loose.	Annual	Mechanic
Inspection	PV Array	Walk through each row of the PV array and check the PV modules for any damage. Report any damage to rack and damaged modules for warranty replacement. Note location and serial number of questionable modules.	Annual	PV Module/Array Specialist
Inspection	PV Array	Inspect ballasted, non-penetrating mounting system for abnormal movement	Annual	Mechanic
Inspection	PV Array	Determine if any new objects, such as vegetation growth, are causing shading of the array and move them if possible. Remove any debris from behind collectors and from gutters.	Annual	Tree Trimming
Inspection	PV Module	Use infrared camera to inspect for hot spots; bypass diode failure	Annual	PV Module/Array Specialist
Inspection	Transformer	Inspect transformer meter, oil and temperature gauges	Annual	Journeyman Electrician
Service	AC Wiring	Re-torque all electrical connections on AC side of system.	Annual	Electrician
Service	DC Wiring	Re-torque all electrical connections in combiner box.	Annual	Electrician
Service	Instruments	Exchange or re-calibrate instruments	As per manuf	Journeyman Electrician
Service	Inverter	Replace transient voltage surge suppression devices	As per manuf	Journeyman Electrician

ACTIVITY AREA	COMPONENT	DESCRIPTION	INTERVAL	SERVICE PROVIDER
Service	Inverter	Install any recent software upgrades to inverter programming or data acquisition and monitoring systems	5 years	Inverter Specialist
Service	Inverter	Clean (vacuum) dust from heat rejection fins	Annual	Inverter Specialist
Service	Inverter	Replace any air filters on air-cooled equipment such as inverter.	As needed	Inverter Specialist
Service	Inverter	Remove any pests such as insects and nests from inverter enclosure; find and repair cracks that pests use to enter the enclosure.	Annual	Vermin Removal
Service	PV Array	Remove bird nests from array and rack area.	Annual	Vermin Removal
Service	PV Array	Nesting vermin removal, nesting vermin prevention	Annual	Vermin Removal
Service	Tracker	Lubricate tracker mounting bearings/gimbals	Annual	Mechanic
Testing	Documents	Perform performance test: measure incident sunlight and simultaneously observe temperature and energy output. Calculate PV module efficiency as a function of temperature and calculate the balance-of-system efficiency. Compare readings with diagnostic benchmark (original efficiency of system).	Annual	PV Module/ Array Specialist
Testing	Inverter	Test over-voltage surge suppressors in inverter	5 Years	Inverter Specialist
Testing	PV Module	Test output of modules that exhibit cracked glass, bubble formation oxidation of busbars, discoloration of busbars, or PV module hot spots (bypass diode failure)	Annual	PV Module/ Array Specialist
Testing	PV Module	Test modules showing corrosion of ribbons to junction box	Annual	PV Module/ Array Specialist

**PV Operations & Maintenance - Design Considerations**

O&M considerations should be included among design criteria such as cost and efficiency. Some of these considerations include:

COMPONENT	DESCRIPTION
AC wiring	Peer review of designs and specifications to ensure constructability by experienced installer.
AC wiring	Perform “facility coordination studies” to avoid problems in AC components between inverter output and point of common coupling (Voss et al, 2009)
Business practice	Provide for operator/technician training in installation of PV system.
DC wiring	Include both ground fault current interrupter and arc-fault detector in design.
DC wiring	A string inverter arrangement is reported to have 0.372% higher energy delivery due to reliability issues than a central inverter arrangement (Wang et al, 2012). Micro-inverter arrangements are reported to be more reliable than string or central inverters (Zhang et al, 2013).
DC wiring	Of five PV module configurations considered, total cross-tied (TCT) and bridge-linked (BL) configurations increase the operational lifetime of the PV arrays by 30% according to Zhang et al (2013).
Grounding	Wang et al (2011) report that of six grounding configurations considered, attaching a tin-plated lay-in lug to aluminum frame with a teeth washer laid between the lug and aluminum surface (Teeth face towards the aluminum surface), had the best reliability under salt mist conditions.
Grounding	Anti-oxidant compound applied between the grounding lug and the module frame increased the mean time to failure of all types of grounding connections considered. (Wang et al, 2011).
Grounding	Wang et al (2011) found that grounding connections that were installed without measuring the applied torque failed 5 times faster than those that were properly installed with a torque wrench.
Inverter	Include internet-connected communications that permit quick fault reporting and diagnostics; remote debugging and re-boot capabilities.
Inverter	Check for defects in high infant mortality items such as interconnects, wiring harnesses, and moving parts.
Inverter	Design redundant systems that have the ability to operate even when full capacity is hindered.
Inverter	Select inverters that observe UL 1741; IPC-9592; EN 60730-1; GBIT 19064; IEC 62109 and 62093.
Inverter	Avoid electrolytic capacitors in favor of solid-state ceramic low-ESR capacitors in order to avoid overheating (Tulkof, 2013); Center for Advanced Life Cycle Engineering has found cracking in ceramic capacitors to be a problem; film technology is ideal for solar inverters because it does not have a short-circuit failure mode, provides for a calculable lifetime, is mechanically robust, and offers appropriate characteristics to maximize inverter efficiency (Granata et al, 2011).
Inverter	Specify AC voltage supervision, in order to limit the overvoltage from inverter that can damage meter or other electronic components (Pazos et al, 2009)
Inverter	Utilize SAC305 instead of SnPb solder (Tulkof, 2013)
Inverter	Specify inverter with DC/DC converter to control and limit DC voltage, in order to limit the AC overvoltage from inverter that can damage meter or other electronic components (Pazos et al, 2009)
Inverter	Of 8 different inverter anti-islanding topologies, Petrone et al (2008) identify General Electric Frequency Shift (GEFS) as the most reliable.

COMPONENT	DESCRIPTION
Inverter	Of 8 different maximum power point tracker (MPPT) topologies, Petrone et al (2008) identifies digital as more reliable than analog and of the digital types “Fuzzy-neuro” and search techniques to be the most reliable.
Inverter	Specify Application-specific Integrated Circuits (ASIC) to combine chips on a printed circuit board thus reducing solder connections and potential for board warping (Tulkoff, 2013).
Inverter	Design features that reduce insulated-gate bipolar transistor (IGBT) voltage failures due to over-voltage include: specify an extra switching voltage margin based on the application (high power?, high temperature?), specify a low inductance bus, and/or snubbers to help reduce overvoltage and resulting “avalanche” failure of IGBT. (Granata, 2011)
Inverter	Take into account solar gains on the enclosure when specifying temperature requirements of inverter.
Inverter	Include in inverter specifications the ability to re-boot inverter control software, clear fault codes, and perhaps install upgrades over a remote monitoring and control system to avoid sending service staff to perform these tasks.
Monitoring	Monitoring systems in initial design; instruments such as current transducers installed permanently in circuit design.
Monitoring	Standardize monitoring communications and control protocols (i.e., EGD, EtherIP, Profinet, etc.)
Monitoring	Add more temperature sensors (ambient, enclosure, IGBT heat sink, etc) to provide intelligence to fault report logs
PV Array	Provide laydown areas, pathways through the array, and places for holes to be opened for smoke ventilation on roof layout.
PV Array	Install bird-spikes on edges to discourage roosting birds
PV Array	Shading analysis, installer evaluation
PV modules	Select and stress-test cells according to UL 1703, ASTM E2481-06 and/or qualification test for crystalline modules IEC 61215; qualification tests for thin-film IEC 61646; and concentrator modules IEC 62108
PV modules	Module construction does not include PV material all the way to edge of the laminate (edge delete).
PV modules	Specify testing according to IEC 61853 Photovoltaic Module Performance Testing and Energy Rating (2010)
PV modules	Carefully select and test bypass and blocking diodes, avoiding module hot spots.
PV modules	Include module manufacturers’ quality practices in selection criteria. Check for: Advanced Product Quality Planning; Failure Modes Effects and Analysis; Fault Tree Analysis; Design for Manufacturability, and Design Review Based on Failure Mode; or other structured approach to quality improvement (Kurtz et al, 2009). ISO 9001 is also a good requirement although it requires only that a process be in place not the details of the tests.
PV modules	Specify low-sodium glass to reduce a source of delamination.
PV modules	Modules incorporating silicone encapsulant showed lower degradation than EVA and polyvinyl butyral encapsulants (Jordan and Kurtz, 2013).
PV modules	Glass–glass modules exhibited larger degradation rates than glass-polymer modules (Jordan and Kurtz 2013)
System	Design to reduce stresses and component count.
System	Include that as-built drawings be delivered as part of design contract
System	Specify components that are “mature” (have passed the qualification test sequence, have been tested in the field for at least 2-5 years, and have been manufactured under a Quality Assurance program.
Transformer	Specify variable control of transformer taps to allow for voltage variations on collection systems, especially in VAR control mode (Granata et al, 2011)



# 569 FW 1 *Integrated Pest Management*

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## 1.1 What is the purpose of this chapter? This chapter:

**A.** Establishes policy, procedures, and responsibilities for pest management activities on and off U.S. Fish and Wildlife Service (Service) lands. It is consistent with the Department of the Interior (Department) Integrated Pest Management policy ([517 DM 1](#)) and other applicable authorities;

**B.** Adopts Integrated Pest Management (IPM) as our method for making pest management decisions; and

**C.** Provides guidance to employees on how to implement IPM for all pest management activities.

## 1.2 What is Integrated Pest Management (IPM)? IPM is:

**A.** A sustainable approach to managing pests that uses the following kinds of tools in a way that minimizes health, environmental, and economic risks:

**(1)** Biological (e.g., predators, parasites, and pathogens),

**(2)** Cultural (e.g., crop rotation, alterations in planting dates, and sanitation),

**(3)** Physical (e.g., barriers, traps, hand-pulling, hoeing, mowing, and tilling), and

**(4)** Chemical (e.g., pesticides, such as herbicides, insecticides, or fungicides).

**B.** A science-based, decisionmaking process that incorporates management goals, consensus building, pest biology, monitoring, environmental factors, and selection of the best available technology to achieve desired outcomes while minimizing effects to non-target species and the environment and preventing unacceptable levels of pest damage.

**1.3 What are pests?** Pests are living organisms, including invasive plants and introduced or native organisms, that may interfere with achieving our management goals and objectives on or off our lands, or that jeopardize human health or safety.

## 1.4 What is the Service's pest management policy? Our policy is to:

**A.** Promote and adopt pest prevention as the first line of defense by using a pathway management strategy such as Hazard Analysis and Critical Control Point (HACCP) planning to prevent unintended spread of species and biological contamination. (See [750 FW 1](#) for more information on HACCP planning).

**B.** Focus on conserving more pristine habitats, monitor these areas, and protect them from invaders.

**C.** Design and maintain the stability of structures, museum collections, and developed landscapes, and restore and maintain habitats to prevent and reduce conditions conducive to the introduction or spread of pests.

**D.** Use IPM methods to eliminate or reduce impacts from vertebrate and invertebrate pests to achieve site-management goals and objectives.

**E.** Use cost-effective pest management practices that pose the least risk to humans, natural and cultural resources, facilities, and the environment.

**F.** Use our best professional judgment and available scientific information to select the lowest risk, most effective IPM method or combination of methods that is feasible for each pest management project. When appropriate, we will include IPM methods in short- and long-term management planning documents such as refuge Comprehensive Conservation Plans, IPM plans, National Environmental Policy Act (NEPA) documents, and invasive species plans. Service IPM planning guidance is on the [Internet](#).

**G.** Encourage pest management activities that benefit natural resources and provide long-term environmentally sound solutions to pest management problems on and off Service lands. This includes planting native species that promote beneficial species, like native pollinators, and promoting beneficial organisms and natural processes that inherently suppress potential pest populations.

**H.** Complete necessary environmental documentation and procedures before conducting pest management activities. This may include:

- (1)** Preparing Pesticide Use Proposals (PUPs) for approval before applying pesticides,
- (2)** Entering pesticide usage information annually into the online IPM and Pesticide Use Proposal System (PUPS) database,
- (3)** Conducting Endangered Species Act consultations, and
- (4)** Following NEPA requirements.

**I.** Use and promote pest management research, methods, education, and technical and financial assistance programs to develop, support, and implement IPM strategies.

**J.** Use appropriate monitoring techniques before, during, and after any IPM activity to determine whether we achieved pest management goals and objectives and if the activity caused any unanticipated impacts.

**K.** When possible, incorporate IPM principles into procurement activities, contracts, leases, and agreements, including activities such as:

- (1)** Cooperative farming,
- (2)** Construction,
- (3)** Habitat management,
- (4)** Fire management,

- (5) Grazing,
- (6) Forestry,
- (7) Operation and maintenance of irrigation systems and dams,
- (8) Concessions management,
- (9) Road and rights-of-way construction and maintenance,
- (10) Public health,
- (11) Animal management, and
- (12) Fish culture.

**1.5 What is the scope of this policy?** This chapter applies to all pest management activities we conduct, approve, or fund on or off Service lands.

**1.6 When will the Service manage pests?** We will manage pests if:

- A. The pest causes a threat to human or wildlife health or private property; action thresholds for the pest are exceeded; or Federal, State, or local governments designate the pest as noxious;
- B. The pest is detrimental to site management goals and objectives; and
- C. The planned pest management actions will not interfere with achieving site management goals and objectives.

**1.7 How does the Service choose which pest management methods to use?** We choose pest management methods by considering the following in this order of importance:

- A. Human safety,
- B. Environmental integrity,
- C. Effectiveness, and
- D. Cost.

**1.8 What are the authorities for this chapter?**

- A. [517 DM 1](#), Integrated Pest Management Policy.
- B. Noxious Weed Control and Eradication Act ([7 U.S.C. 7701 et seq.](#), Subtitle E).
- C. Federal Property Management Regulations, Facility Management ([41 CFR 102-74.30](#)).
- D. Agriculture Risk Protection Act ([PL 106-224](#)) (supersedes the Federal Noxious Weed Act, except Sections 11 and 15).

E. [Executive Order 13112](#), Invasive Species.

F. National Wildlife Refuge System Administration Act ([16 U.S.C. 668dd- 668ee](#)), as amended by the National Wildlife Refuge System Improvement Act ([P.L. 105-57](#)).

G. National Invasive Species Act ([P.L. 104-332](#)).

H. Aquatic Nuisance Prevention and Control Act ([P.L. 101-646](#)).

I. Endangered Species Act ([16 U.S.C. 1536](#)).

J. Occupational Safety and Health Act ([P.L. 91-596](#)).

K. The National Environmental Policy Act ([42 U.S.C. 4321-4370d](#)).

L. Federal Water Pollution Control Act ([33 U.S.C. 1251 – 1376](#)) (also known as Clean Water Act).

M. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) ([7 U.S.C. 136](#)).

N. Migratory Bird Treaty Act ([16 U.S.C. 703-716](#)).

O. Official Animal Control Operations ([50 CFR 31.14](#)).

### 1.9 Who is responsible for IPM?

A. The **Director** approves Servicewide IPM policy.

#### B. The **Assistant Director – Fisheries and Habitat Conservation:**

(1) Designates a National IPM Coordinator to coordinate a consistent Servicewide approach to pest management,

(2) Designates a liaison in the Fisheries program to work closely with the National IPM Coordinator to promote policy compliance and coordination, and

(3) Ensures the development and distribution of information on innovative and updated pest management techniques.

#### C. The **Assistant Director – National Wildlife Refuge System:**

(1) Designates a liaison to work closely with the National IPM Coordinator to ensure the Refuge System's policy compliance and coordination,

(2) Supports national IPM activities, including maintenance of the national IPM and PUPS database, and

(3) Designates an IPM and PUPS database administrator (owner) for the Refuge System.

D. The **Assistant Director – Wildlife and Sport Fish Restoration Program** encourages grantees to implement IPM strategies when managing pest species on projects and lands for which we provide grants.

**E. The Assistant Director – External Affairs** ensures that the National Conservation Training Center develops and offers IPM and other pesticide-related training.

**F. The Assistant Director – Business Management and Operations** ensures we incorporate IPM principles into procurement activities, contracts, leases, and agreements.

**G. The Regional Directors:**

(1) Ensure Regional compliance with this policy.

(2) Designate a Regional IPM Coordinator who informs employees about innovative and new IPM techniques.

(3) Ensure that employees receive training necessary to competently develop and implement IPM programs. Such training may include IPM planning, pesticide applicator certification, and pest species management.

(4) Ensure that performance plans and annual work activity guidance for employees responsible for pest management reflect the goals and objectives of this policy.

(5) Use funds allocated for pest management for appropriate pest management projects.

(6) Ensure that staff keep records of IPM techniques, including use of pesticides, biocontrols, and other pest management tools on lands we manage, and that these records are available as needed.

**H. The National IPM Coordinator:**

(1) Develops, maintains, and distributes information about innovative and current pest management techniques to Regional personnel.

(2) Attends and helps organize a national IPM workshop annually or as needed. This workshop is for national, Regional, and field staff who participate in IPM activities.

(3) Serves on a Federal IPM Coordination Group with IPM Coordinators from many Federal agencies, including the Environmental Protection Agency, U.S. Department of Agriculture, General Services Administration, Bureau of Land Management, and the National Park Service. Serves on other IPM coordination groups as appropriate.

(4) Approves or disapproves IPM plans and PUPs that require Headquarters review and approval to ensure compliance with applicable laws and other authorities (see [section 1.11](#)).

(5) Promotes awareness of and compliance with the Departmental IPM policy to provide a consistent national approach to pest management.

(6) Reviews annual Regional IPM reports, including pesticide use data, generated by the PUPS database.

(7) Coordinates closely with field and Regional staff implementing IPM activities to ensure environmental compliance and to promote the most streamlined procedures and reporting methods.

(8) Works with field and Regional staff implementing IPM to develop updates, as necessary, to

national guidance, including the appropriate review level for different IPM activities (e.g., specific pesticide applications).

#### **I. Regional IPM Coordinators:**

- (1)** Approve or disapprove IPM plans and PUPs requiring their review to ensure compliance with applicable laws and other authorities (see [section 1.11](#)). This includes reviewing PUPs in an emergency when an unanticipated outbreak occurs. If a PUP requires Headquarters review, the Regional IPM Coordinator must send it to Headquarters even in an emergency.
- (2)** Provide the National IPM Coordinator with information concerning pesticide applications or other IPM techniques, when requested.
- (3)** Coordinate with the National IPM Coordinator when the National IPM Coordinator has to review a PUP from their Region.
- (4)** Work with the National IPM Coordinator to develop updates, as necessary, to national guidance, including the appropriate review level for different IPM activities (e.g., specific pesticide applications).
- (5)** Provide Regional personnel with information about environmental hazards and updated pest management techniques.

#### **J. Project Leaders:**

- (1)** Ensure that pest management decisions are consistent with this policy, the pesticide safety policy ([242 FW 7](#)), laws, and regulations, including, but not limited to:
  - (a)** Local, State, and Federal requirements for informing employees and visitors of pesticide use,
  - (b)** The Endangered Species Act (for some projects this may include consultation under section 7 of the Act),
  - (c)** NEPA, and
  - (d)** The Federal Insecticide Fungicide and Rodenticide Act (FIFRA).
- (2)** Develop IPM plans, as appropriate, consistent with NEPA documentation.
- (3)** Work with the Regional IPM Coordinator to ensure pest management activities use IPM strategies consistent with resource management goals and objectives, such as those stated in Comprehensive Conservation Plans or similar plans.
- (4)** Promote and encourage IPM practices to land owners and others whose pesticide use may affect Service lands and resources.
- (5)** Ensure that anyone applying pesticides, releasing biological control agents, and conducting other IPM activities has the appropriate training and equipment necessary to protect their safety and health (also see [242 FW 7](#)).
- (6)** Ensure we apply pesticides only after the appropriate reviewer (see [section 1.11](#)) approves the PUP. We determine who must review and approve PUPs based on pesticide characteristics and its usage pattern. The National IPM Coordinator works with a national team of Regional IPM and

Invasive Species Coordinators to determine the level of review and approval each pesticide receives.

**(7)** Help establish threshold levels of damage or pest populations according to Service or field station goals and objectives and applicable laws.

**(a)** Before the treatment, verify that the site has damage levels or pest populations that exceed threshold levels.

**(b)** After the treatment, determine whether the pest management action achieved the desired results and whether there were any unanticipated or non-target impacts.

**(8)** Provide the Regional IPM Coordinator with summaries of IPM activities at his/her request.

**(9)** Ensure that staff store, handle, and dispose of pesticides and pesticide containers in accordance with the label, as required by law, and in a manner that safeguards human, fish, and wildlife health and prevents soil, air, and water contamination.

### **1.10 What kind of training do employees need before they can apply pesticides?**

**A.** People who apply pesticides on Service lands must have proper training and pesticide certification, as required by Federal and State laws.

**B.** To purchase, use, or supervise the use of Restricted Use Pesticides, the person must be a Certified Pesticide Applicator (Commercial Applicator), under Section 4 of FIFRA or under the direct supervision of Certified Pesticide Applicator.

**(1)** A Restricted Use Pesticide is a pesticide product that has a relatively high degree of potential for human or environmental hazard even when it's used according to label directions.

**(2)** We encourage people who apply general pesticides (non-Restricted Use Pesticides) or supervise these applications to become Certified Pesticide Applicators (see [242 FW 7](#)), even if certification is not required by law.

**1.11 What do employees have to do before applying pesticides?** We may only apply pesticides after filling out a PUP and getting PUP approval. A PUP is an online document that identifies important considerations related to a pesticide application (e.g., goals, objectives, IPM techniques, best management practices, pesticide application rates and methods, etc.).

**A.** The appropriate field station or facility employee must complete a PUP in the online PUPS database. We use the PUPS database to develop, duplicate, submit, review, and approve or disapprove a PUP.

**B.** PUP reviewer(s) examine the PUP for compliance with applicable regulations to ensure that employees use the least risk and the most specific and effective pesticide(s) to manage the target pest. The National IPM Coordinator works with a national team of Regional IPM and Invasive Species Coordinators to determine the level of review and approval each pesticide receives. The National IPM Coordinator updates this review and approval hierarchy and the resulting pesticide lists as needed.

**C.** Approvals and disapprovals only apply to the specific application regime, time, location, pesticide, and target pest.

(1) Depending on the PUP, the Project Leader may review and approve it, or he/she may send it to the Regional IPM Coordinator for review and approval. The Regional IPM Coordinator has to send some PUPs to the National IPM Coordinator for review and approval.

(2) Regardless of whether the PUP needs just the approval of the Project Leader or the approval of the Regional or National IPM Coordinator, or both, each approving authority has 30 days to conduct the review (so a PUP that has to go to the National IPM Coordinator could take up to 90 days).

(3) The review period may take longer depending on what changes the PUP may need and the PUP workloads at the different reviewer levels. Also, an expedited PUP review may be necessary when there is an emergency pest outbreak.

**1.12 Does the Service require IPM plans for pesticide applications?** No. We encourage employees engaging in pest management practices to include a separate pest management plan or incorporate IPM strategies into other resource planning documents (e.g., Comprehensive Conservation Plans, Environmental Assessments, and Environmental Impact Statements). When developing an IPM plan, we encourage employees to ensure it conforms to the parameters of an Environmental Assessment or Environmental Impact Statement, as appropriate. Doing this benefits Project Leaders because they may receive multi-year approvals of certain proposed pesticide uses that would normally require Regional or national level review.

**1.13 What is the relationship among IPM plans, Comprehensive Conservation Plans, and NEPA?** Employees must develop the appropriate level of NEPA documentation (conforming to the parameters of a categorical exclusion, Environmental Assessment, or Environmental Impact Statement) and provide public involvement, as needed, when they develop IPM plans. If you have identified, addressed, and authorized specific pest management strategies in a Comprehensive Conservation Plan and fully evaluated these strategies in the Comprehensive Conservation Plan's NEPA document, you do not need further NEPA documentation. For more information on NEPA compliance, see Departmental and Service NEPA guidance in [516 DM 6](#), Appendix 1 and [550 FW 3](#).

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**242 FW 7**  
***Pesticide Users  
Safety***

Supersedes 242 FW 7, FWM 272,  
09/30/96  
Date: December 4, 2009  
Series: Occupational Safety and  
Health  
Part 242: Industrial Hygiene  
Originating Office: Division of Safety  
and Health

[PDF Version](#)

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**7.1 What is the purpose of this chapter?** This chapter outlines the Service's requirements and responsibilities for implementing a Pesticide Users Safety Program for those involved in pesticide-related activities on and off Service lands.

**7.2 What is the Service policy for pesticide user safety?** The Occupational Safety and Health Administration (OSHA) requires that the Service protect personnel from on-the-job exposure to pesticides (e.g., insecticides, fungicides, herbicides, or rodenticides) that can cause adverse health effects.

**7.3 To whom does this chapter apply?**

**A.** This chapter applies to the following whose work involves mixing, formulating, loading, applying, transporting, storing, and disposing pesticides:

- (1) Service employees and staff,
- (2) Volunteers,
- (3) Youth Conservation Corps enrollees and supervisors, and
- (4) Seasonal workers.

**B.** Contractors, such as cooperative farmers, and others, such as Mosquito Abatement Districts, are responsible for their own safety and health program and must comply with OSHA and Environmental Protection Agency requirements.

**7.4 What is the scope of this chapter?**

**A.** This chapter covers the following pesticide-related activities:

- (1) Mixing, formulating, loading, applying, transporting, and storing pesticides;
- (2) Disposing of pesticides and emergency spill clean-up activities; and
- (3) Developing and monitoring contracts or permits involving the application and use of pesticides by non-Service personnel on Service-owned or leased property.

**B.** This chapter does not cover the incidental use of "general use" aerosol pesticides sold for home use or over-the-counter repellents intended for direct application to humans or pets. All pesticide uses, including those excluded from this policy, are subject to Departmental and Service Pesticide and Integrated Pest Management policies.

**7.5 What are the authorities for this chapter?**

**A.** Occupational Safety and Health Act of 1970, Section 19, Federal Agency Safety Program and Responsibilities ([Public Law 91-596](#)).

B. [Executive Order 12196](#), Occupational Safety and Health Programs for Federal Employees, February 26, 1980.

C. Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters ([29 CFR 1960](#)).

D. Occupational Safety and Health Standards ([29 CFR 1910, Table 1000](#)).

E. Pesticide Programs, Worker Protection Standard ([40 CFR subchapter E, Part 170](#)).

F. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) ([7 U.S.C. 136-136y](#)).

G. [517 DM 1](#), Department of the Interior Integrated Pest Management Policy.

H. Department of the Interior's Occupational Medicine Handbook.

## 7.6 Who is responsible for the Pesticide Users Safety Program?

### A. The Director:

(1) Ensures that we maintain an effective and comprehensive occupational safety and health program, and

(2) Approves our pesticide users safety policy.

### B. The Assistant Director – Business Management and Operations ensures that:

(1) We have a pesticide users safety policy, and

(2) Headquarters provides sufficient support and resources to implement the policy.

### C. The Chief, Division of Safety and Health:

(1) Revises and updates this chapter, as necessary, and

(2) Provides interpretation of the requirements of this chapter and serves as a consultant to resolve Servicewide issues or questions.

### D. Regional Directors and the Director, National Conservation Training Center:

(1) Provide sufficient support and resources to effectively implement the requirements of this chapter within their Regions.

(2) Ensure that staff in their Regions provide the following services:

(a) Evaluate implementation of the requirements of this chapter during safety and environmental program audits, and

(b) Assist Project Leaders/Supervisors/Facility Managers in developing a pesticide user's safety program that includes job hazard assessments, emergency spill response plans, medical surveillance procedures, storage and disposal procedures, identification of appropriate personal protective equipment, and proper training.

(3) Ensure that staff implement procedures for protection of personal medical information in accordance with the Privacy Act and other applicable authorities.

**E. The Chief, Division of Environmental Quality** provides oversight and recommendations consistent with the safety and health requirements of this chapter when reviewing Pesticide Use Proposals (PUPs) that require approval by Headquarters.

**F. Regional Integrated Pest Management (IPM) Coordinators** provide oversight and recommendations consistent with the safety and health requirements of this chapter when reviewing PUPs that require approval by the Regional Office.

**G. Regional Safety Managers:**

(1) As requested, provide technical support to Project Leaders/Supervisors/Facility Managers, Regional IPM Coordinators, Regional Environmental Contaminants Coordinators, or other appropriate personnel to interpret the requirements of this policy and assist with the development of job hazard assessments; and

(2) Evaluate the implementation of the requirements of this chapter during field station safety audits.

**H. Project Leaders/Supervisors/Facility Managers** must:

(1) Ensure that:

(a) Pesticide users under their supervision are enrolled in an appropriate medical monitoring program based on the parameters in [section 7.12](#);

(b) A physician or physician's assistant has determined that employees who will be mixing, formulating, loading, applying, transporting, storing, and disposing pesticides are medically able to accomplish assigned tasks (see [section 7.12](#)); and

(c) Staff implement procedures for protecting personal medical information in accordance with the Privacy Act and other applicable authorities (see [section 7.12](#)).

(2) Ensure that pesticide users under their supervision use the appropriate personal protective equipment as described on the pesticide label and in accordance with an approved job hazard assessment. If personal protective equipment requirements call for a respirator, see [242 FW 14](#), Respiratory Protection for guidance.

(3) Prepare a job hazard assessment ([240 FW 1](#)), including tasks to be performed, associated hazards, and required personal protective equipment for personnel subject to this policy.

(4) Ensure that the Material Safety Data Sheets (MSDSs) for all pesticide products used at the station are readily available and accessible to all workers. In addition, personnel who are mixing, formulating, loading, applying, transporting, storing, and disposing pesticides must have appropriate labels and MSDSs at the job site.

(5) Ensure the proper handling, storage, management, and disposition of pesticides.

(6) Notify their Fire Management Officer or contracted fire fighting entities if a prescribed burn occurs or is planned to occur or a wildfire occurs in an area treated with pesticides within 90 days of the treatment.

(7) Consult with the Regional Safety Manager regarding the interpretation of the requirements of this chapter.

**I. Pesticide Users:**

- (1) Participate in medical monitoring programs (see [section 7.12](#));
- (2) Attend required training (see [section 7.18](#)) and maintain State-required certification. Provide training completion information and copies of training certificates to the Project Leader/Supervisor/Facility Manager;
- (3) Follow all policies and procedures required for the tasks assigned;
- (4) Wear the appropriate personal protective equipment as described on the pesticide label and in accordance with an approved job hazard assessment. If personal protective equipment requirements call for a respirator, see [242 FW 14](#), Respiratory Protection for guidance;
- (5) Notify the Project Leader/Supervisor/Facility Manager if their physical or medical conditions preclude assignment in pesticide-related field activities involving mixing, loading, formulating, transporting, applying, storing and disposing pesticides; and
- (6) Take corrective action within their limits of authority and report to their Project Leader/Supervisor/Facility Manager those hazards that they cannot safely abate.

### 7.7 What terms do you need to know to understand this chapter?

**A. Frequent Pesticide Use** means when a person applying pesticide handles, mixes, or applies pesticides, with a Health Hazard rating of 3 or higher, for 8 or more hours in any week or 16 or more hours in any 30-day period. We consider any less frequent pesticide use to be infrequent use. Because there are no restrictions on the frequency of using pesticides with a health hazard rating of 1 or 2 other than what the manufacture requires on the label/MSDS, they aren't included when we discuss frequent use.

**B. General Use Pesticides** are those products that will not cause unreasonable adverse effects when used according to widespread and commonly recognized practices.

**C. Health Hazard** is the potential for acute or chronic adverse health effects that can result from exposure to a chemical or mixture of chemicals as documented through one or more scientific studies. Chemicals can be hazardous if they are:

- (1) Carcinogens;
- (2) Reproductive toxins;
- (3) Irritants;
- (4) Corrosives;
- (5) Sensitizers;
- (6) Hepatotoxins;
- (7) Nephrotoxins;
- (8) Neurotoxins;
- (9) Agents that act on the blood forming system;
- (10) Agents that damage the lungs, skin, eyes, or mucous membranes; and

(11) Other toxic agents.

**D. Health Hazard Rating**, as defined by the National Fire Protection Association, is the degree of health hazard of a chemical or material based on the form or condition of the material and its inherent properties. The degree of health hazard of a material should indicate the degree of personal protective equipment required for working safely with the material. Health hazard ratings can be found on most MSDSs in either the "Other Information" or the "Fire & Explosives Hazard" section. Consult the MSDS for specific health hazards and proper personal protective equipment to use with all materials.

**1** is for slightly hazardous (toxic) material that requires only minimal protection (e.g., safety glasses and gloves) and normal work clothing to work with safely.

**2** is for moderately toxic or a hazardous or moderately toxic material that requires additional personal protective equipment or other equipment (e.g., chemical goggles, lab/work smock, local ventilation) in addition to that required for less toxic material. Consult the MSDS for specific health hazard and proper personal protective equipment to use with this material.

**3 or 4** is for highly to extremely toxic (deadly) materials (and any carcinogen, mutagen, or teratogen). These materials require specialized equipment (e.g., respirator or exhaust hood, full face shield, rubber apron, specialized gloves, handling tongs, etc.) beyond that required for moderately toxic material. You must consult the MSDS and other safety information to determine the hazard (acute or chronic) and the proper personal protective equipment and engineering controls to safely use this material.

**E. Integrated Pest Management (IPM)** is a sustainable approach to managing pests by combining biological (e.g., natural predators), cultural (e.g., crop rotation), physical (e.g., traps), and chemical tools in a way that minimizes economic, health, and environmental risks.

**F. Permissible Exposure Limit (PEL)** is the maximum amount of exposure to, inhalation of, or skin contact with chemical or physical agents under the Occupational Safety and Health Act.

**G. Pest** is:

(1) Any insect, rodent, nematode, fungus, weed; or

(2) Any other form of terrestrial or aquatic plant or animal life or virus, bacteria, or other microorganism (except viruses, bacteria, or other microorganisms on or in living man or other living animals) that the Environmental Protection Agency declares to be a pest under FIFRA.

**H. Pesticide** is any substance or mixture of substances intended for controlling, preventing, destroying, repelling, or mitigating any pest, and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant.

**I. Pesticide Users** are those whose work involves mixing, formulating, loading, applying, transporting, storing, and disposing pesticides.

**J. Restricted Use Pesticide (RUP)** is a pesticide that is available for purchase and use only by those certified to apply pesticide or people under their direct supervision. Pesticides are designated as RUPs because of their relatively high degree of potential human or environmental hazard even when used according to label directions.

**K. Threshold Limit Values** are airborne concentrations of substances and represent conditions under which the safety and health industry believes that nearly all workers may be repeatedly exposed without adverse health effects. The American Conference of Governmental Industrial Hygienists establishes threshold limit values.

**7.8 What are the safety and health issues Service employees should consider when addressing pesticide user's safety?** All offices involved with pesticide-related activities must consider a large amount of safety and health information before starting field work.

**A.** Those applying pesticides and their Project Leaders/Supervisors/Facility Managers must consider, at a minimum, the following types of health and safety information:

- (1) Job hazard assessments,
- (2) Pesticide application guidelines,
- (3) Medical monitoring programs,
- (4) Training,
- (5) Certification,
- (6) Storage and disposal, and
- (7) Documentation.

**B.** We encourage employees to use pesticide products that deliver the intended effect and pose the least hazard.

### **7.9 What are the elements of a Job Hazard Assessment?**

**A.** The Project Leader/Supervisor/Facility Manager evaluates projects requiring the use of pesticides to identify specific hazards including those related to the pesticide, method of application, site to be treated, and personal protective equipment required. We must be careful to ensure that employees and the public are not exposed to harmful quantities of chemicals that are known or suspected of causing adverse human health. Before using pesticides, managers must comply with the requirements of this chapter, pesticide labels, and other applicable Service policies (also see [240 FW 1](#)). For an example of job hazard assessment for pesticide-related activities see [Exhibit 1](#) (PDF file).

**B.** Project Leaders/Supervisors/Facility Managers must maintain MSDSs for each hazardous chemical used during pesticide-related activities and ensure they are readily accessible to employees engaged in pesticide-related activities.

### **7.10 What are the guidelines for Service pesticide users? We must:**

**A.** Consider the use of pesticide products that deliver the intended effect and pose the least hazard to human health.

**B.** Mix, formulate, load, apply, transport, store, and dispose of pesticides in a manner consistent with the methods, rates, and equipment specified on the label and applicable State and local requirements.

**C.** Select application methods that minimize exposure to the people applying them, other employees, the general public, and non-target organisms.

**D.** Apply pesticides in or around Service residences, dormitories, and offices at a time dictated by the product's element of risk (i.e., high risk to low risk). Those products with a high risk to human health will often have a required "Re-entry Interval" (REI) indicated on the label or MSDS. Those with a low risk to human health (e.g., ant or cockroach bait traps) will not have such restrictions

and require no occupancy limitations. Project Leaders/Supervisors/Facility Managers at facilities using products that have an REI indicated on their label must restrict access to that facility or area for the duration of the REI.

**E.** Ensure that procedures and necessary supplies are provided at the field stations to address pesticide mixing and loading areas for containment and cleanup of spilled chemicals and for backflow prevention (anti-siphoning devices) on water sources so that piped drinking water supplies aren't contaminated (see [29 CFR 1910.151](#)).

**F.** Notify employees, visitors, volunteers, and the public, as appropriate, before applying pesticides that have a required REI. This notification must be a posting that indicates a point of contact, the point of contact's telephone number, and the REI.

**7.11 What are the components of our medical monitoring program?** We have implemented a medical program that requires personnel who engage in pesticide-related activities, as described in [section 7.12](#), to undergo a medical examination and medical monitoring. The examinations are to assess an individual's ability to safely perform pesticide-related activities. Subsequent monitoring (i.e., laboratory testing) assists the occupational health professional to detect any absorption through the skin, gastrointestinal system, or by inhalation. Occupational health professionals also use medical examinations and monitoring results to assess body burden, reconstruct past exposure, monitor work practices, and assess the effectiveness of personal protective equipment and in-place controls.

**7.12 Who is included in the medical monitoring program?**

**A.** We include personnel in the medical examination and monitoring program if they:

- (1) Have been exposed or may be exposed to concentrations at or above the published permissible exposure limits or threshold limit values (see [242 FW 4](#));
- (2) Use pesticides in a manner that that we consider "frequent pesticide use" (see [section 7.7](#)); or
- (3) Use pesticides in a manner that requires a respirator (see [242 FW 14](#) for respirator use requirements).

**B.** Under some circumstances, we may include employees who use pesticides infrequently (see [section 7.7](#)), experience an acute exposure (sudden, short term), or use pesticides with a health hazard ranking of 1 or 2 in the medical examination and monitoring program. We base the decision about whether or not to include them in medical monitoring on the individual's health and fitness level, the pesticide's specific health risks, and the potential risks from other pesticide-related activities.

**C.** If you are using or considering the use of a product that does not have a National Fire Protection Association health hazard rating, consult with your Regional safety office or the Division of Safety and Health. Also consider the points in Table 7-1 to make informed decisions on setting a rating when one doesn't exist.

<b>Table 7 1: Product Factors for Consideration</b>
<b>Ask the following when a product doesn't have a National Fire Protection Association Health Hazard Rating...</b>
Does the product have any constituents that are carcinogens?
Where does the product's technical information fall within the Health Hazard and Health Hazard Rating definitions?
How are you applying or planning to apply the product?

How much personal protective equipment is required?

**7.13 Who determines if medical monitoring is necessary?** The Regional Safety Manager, Project Leader/Supervisor/Facility Manager, and occupational health professional(s) should collectively make the decision about whether to include an employee in the medical monitoring program based on the criteria in [section 7.12](#).

**7.14 How does the Service use the results of medical monitoring?** We use the results of medical monitoring to identify whether an employee has been exposed to pesticides, re-evaluate personal protective equipment selection and handling procedures, and determine if an employee is eligible for continued participation in pesticide-related activities. If examinations or monitoring test results indicate that an employee is not physically able to participate in routine pesticide-related activities because of occupational exposure to pesticides or other medical conditions, we remove the employee from exposure. These activities may not be resumed without a medical release.

**7.15 Where do personnel go for pesticide-related medical services?** We encourage the Regions to use the Federal Occupational Health (FOH) units of the U.S. Public Health Service (USPHS) to the extent possible. You can use other sources of occupational health services (i.e., local clinics or private physicians) if available. See [Exhibit 2](#) for guidance on the examination process.

**7.16 What are the requirements of medical examinations?**

**A.** We require an exam (baseline, periodic, and termination) that constitutes a medical history, exposure history, and complete physical examination for all participants in the medical monitoring program. Typically the frequency of monitoring (e.g., blood counts) is annual, but the occupational health professional may require more or less.

**B.** Not participating in any phase of a required medical examination/monitoring program may result in disciplinary action, reassignment, or in a worse case scenario, dismissal from the job.

**C.** A Reviewing Medical Officer uses examinations and laboratory test results to determine whether to issue clearance for an employee to conduct pesticide-related activities. The clearance states whether or not the person is physically and medically able to perform his/her duties. If the official determines an employee is unable to perform his/her duties or places restrictions on activities, the clearance document states this and identifies the reasons.

**D.** See Table 7-2 for a list of the forms we use for pesticide medical exams.

**Table 7 2: Medical Exam Related Forms**

[FWS Form 3-2395](#), Recommended Exams & Tests for Pesticide Users

[FWS Form 3-2396](#), Pesticide Use Profile

[FWS Form 3-2397](#), Pesticide Exam Medical Release & Physician Clearance

[FWS Form 3-2399](#), FOH Medical History and Examination Form for Pesticide Workers

**E.** We set up these exams as a joint protocol so that we can also use them for people with additional duties, such as Arduous Duty Wildland Fire Fighters. (The requirements meet those of the fire medical standards annual exam.) The employee should take [Exhibit 3](#) (PDF file) with them to the doctor as well as the other forms listed in Table 7-2.

**F.** Employees who have participated in the medical monitoring program described in this chapter must be provided with a termination physical examination before their separation date from the Service.

**G.** All examination and laboratory test results must be sent to the Service's Reviewing Medical Officer for Pesticide Applicators for review (see [Exhibit 2](#)).

**7.17 What are the requirements for mixing, storing and disposing of pesticides? We must:**

**A.** Mix and store all pesticides in accordance with the pesticide labels and applicable Federal, State, and local laws and regulations.

**B.** Separate pesticides from flammable or incompatible chemicals and secure them from unauthorized access. Provide good ventilation and secondary containment in the storage, preparation, and mixing areas. Maintain in an accessible location chemical spill kits that are compatible for the pesticides stored or used.

**C.** Label portable pesticide containers with the name of the chemical and appropriate hazard warnings.

**D.** Dispose of all pesticide containers in accordance with the pesticide label. This may involve triple rinsing containers into the sprayer, if possible.

**E.** Protect storm and sanitary drains from spillage. Never put pesticides into the sewer or trash without proper clearance from regulatory agencies.

**F.** Ensure expired or unneeded pesticides are properly identified, managed, and disposed of in accordance with Federal, State, and local regulations. Contact local and State regulatory agencies for approved disposal options and facilities.

**G.** Maintain an inventory of pesticides, their use, and a record of the final disposition of any wastes.

**7.18 What are the training requirements for applying pesticides? We must train personnel before they begin work with pesticides.**

**A.** Pesticide users must have pesticide training and certification required by applicable policies and regulations. The Environmental Protection Agency (EPA) regulations require that people applying pesticides be certified as competent to apply Restricted Use Pesticides. States, territories, tribes, and some Federal agencies have EPA-approved certification programs. For safety reasons, we also encourage all personnel who conduct pesticide-related activities with general use pesticides to acquire pesticide applicator certification. Verify with the applicable State whether the certification requirement is for a commercial or private applicator.

**B.** Project Leaders/Supervisors/Facility Managers and other employees involved in pesticide-related activities (i.e., general use application) must be trained to recognize potential hazards and minimize personal exposure by using proper procedures and personal protective equipment. We achieve this through a comprehensive hazard communication program (see [242 FW 2](#)). The hazard communication program must specifically address:

**(1)** Signs and symptoms of over-exposure to pesticides;

**(2)** Appropriate selection and use of personal protective equipment;

**(3)** Proper type and limitations for pesticide applications as outlined in an applicable job hazard

assessment;

(4) Proper use, storage, spill containment, and disposal of pesticides. The Regional Spill Coordinators can give you information on spill response training;

(5) Legal requirements for following all instructions on the pesticide label; and

(6) Users' ability to read and understand MSDSs.

**7.19 Are there any other safety requirements associated with applying pesticides?** All personnel must follow these additional safety requirements and personal safety practices to minimize the risk of exposure during pesticide-related activities:

**A.** Employees must not eat, drink, chew gum or tobacco, smoke, etc. while conducting pesticide-related activities.

**B.** After conducting pesticide-related activities, employees must thoroughly wash their hands and face. If applying pesticides at a field location where there is no access to hand washing facilities, the applicators should carry hand wipes in their vehicle so they can wipe off their hands and face before eating and drinking.

**C.** We do not allow employees to apply pesticides that require tight-fitting, negative pressure respirators (see [242 FW 14](#)) if their facial hair interferes with the mask-to-face seal.

**D.** Avoid contact with pesticide-contaminated surfaces or treated areas. For example, do not walk through puddles or other discolored surfaces, kneel on the ground, or place equipment on containers or on visibly contaminated surfaces. Adhere to a pesticide's REI.

**E.** Provide suitable facilities for quick drenching or flushing of the eyes and body within the immediate work area where contact with materials occurs.

**7.20 What are the personal protective equipment requirements?** Personal protective equipment selection and use varies depending on the chemical you are mixing, loading, or applying; where it is used; and how it is used. Employees may use more personal protective equipment than what is required as long as it does not create additional hazards.

**A.** All personal protective equipment use and maintenance, including cleaning and storage, must comply with the pesticide label and [241 FW 3](#), Personal Protective Equipment.

**B.** Employees required to wear respirators during pesticide application must comply with all elements of their station's Respiratory Protection Program (see [242 FW 14](#) and [29 CFR 1910.134](#)).

**C.** If personnel wear non-disposable clothing (i.e., uniforms or coveralls, etc.) when applying pesticides, they must keep that clothing separate from the clothing they take home, and they must not wash that clothing at home. If suitable laundry equipment is not provided, then personnel who conduct pesticide-related activities must use disposable clothing (e.g., coveralls).

**D.** Personnel must change clothing they wear during applications before using vehicles or entering office locations. Personal protective equipment and other equipment must be decontaminated when operations are complete.

**7.21 What are the documentation requirements for this chapter?**

**A.** Project Leaders/Supervisors/Facility Managers must retain:

- (1) A written record of all pesticide-related training and other training that addresses safe handling of pesticides that employees receive (see [section 7.18](#)),
- (2) Job hazard assessments for as long as the related projects last,
- (3) Exposure sampling results for a minimum of 30 years [[29 CFR 1910.1048\(o\)](#)],
- (4) Respirator fit testing and medical clearance records until replaced by a more recent record,
- (5) Medical clearance for doing pesticide-related activities until a new clearance is received, and
- (6) A written record of routine monthly flushing of eyewashes and emergency showers, and any periodic maintenance performed per the manufacturer's standards for portable eyewash units.

**B.** The servicing Human Resources office must retain all medical evaluations such as physician opinions, physical exam results, physical exam supporting documentation, etc. for, at a minimum, the length of employment plus 30 years. Human Resources should retain these documents in the employee's Employee Medical Records, SF-66D.

**C.** We must collect and maintain records containing personal information (e.g., medical evaluations and physician statements, etc.) in compliance with [5 U.S.C. 552a](#) (The Privacy Act of 1974). Employees tasked with storing and maintaining such records must read and be familiar with OPM/GOVT-10. These records:

- (1) Are sensitive and protected by The Privacy Act (see [204 FW 1 – 8](#) for more information on the Privacy Act),
- (2) Must only be available to staff on a need-to-know basis,
- (3) If electronic, must be password protected and only used in accordance with the routine uses identified in "OPM/GOVT-10, Employee Medical File System Records," and
- (4) If hard copy, protected in a locked file and locked room that is available only to staff who have a need to know this information in accordance with OPM/GOVT-10.

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**PV Corrective Maintenance - Service Descriptions**

<b>ACTIVITY</b>	<b>COMPONENT</b>	<b>Service Description</b>	<b>Frequency/ Response Time</b>	<b>Service Provider</b>
Emergency Response	System	Dispatch contractor in response to alarms, alerts, or contact by others	As needed	Journeyman Electrician
Management	Asset Management	Warranty coordination: administer timely response for claims and repairs	As needed	Admin Asst
Repair	AC wiring	Replace inverter AC fuse(s)	As needed	Electrician
Repair	AC wiring	Replace protective devices (breakers) in building panel	As needed	Electrician
Repair	AC wiring	Replace broken/crushed AC wiring conduit and fittings	As needed	Electrician
Repair	AC Wiring	Repair line-to-line fault	As needed	Electrician
Repair	AC Wiring	Locate line-to-line fault	As needed	Inspection
Repair	DC Wiring	Replace failed fuses in combiner box.	As needed	Electrician
Repair	DC Wiring	Replace any electrical boxes that have extensive corrosion, make sure junction boxes are sealed.	As needed	Electrician
Repair	DC wiring	Replace MC Connectors between modules	As needed	Electrician
Repair	DC wiring	Replace MC connector lead to combiner box	As needed	Electrician
Repair	DC wiring	Replace failed fuses in combiner box	As needed	Electrician
Repair	DC wiring	Replace fuse(s) on DC source circuits to inverter	As needed	Electrician
Repair	DC wiring	Re-route conduit	As needed	Electrician
Repair	DC wiring	Replace broken/crushed Dc wiring conduit and fittings	As needed	Electrician
Repair	DC Wiring	Repair ground fault	As needed	Electrician
Repair	DC Wiring	Locate ground fault	Annual	Inspection
Repair	DC wiring	Locate underground DC wiring	As needed	Specialist
Repair	Inverter	Replace fuse	As needed	Journeyman Electrician
Repair	Inverter	Start/stop inverter (reboot to clear unknown error)	As needed	Journeyman Electrician
Repair	Inverter	Replace inverter fan motor	As needed	Inverter Specialist
Repair	Inverter	Replace inverter data acquisition card/board (also called system input module); diagnose with fault code	As needed	Inverter Specialist
Repair	Inverter	Replace inverter data acquisition card/board; diagnose with fault code	As needed	Inverter Specialist

ACTIVITY	COMPONENT	Service Description	Frequency/ Response Time	Service Provider
Repair	Inverter	Replace inverter control card (PWM signal, voltage, phase, frequency, shut-down); diagnose with fault code	As needed	Inverter Specialist
Repair	Inverter	Replace IGBT driver card/board; diagnose with fault code	As needed	Inverter Specialist
Repair	Inverter	Replace maximum power point tracker card/board; diagnose with fault code	As needed	Inverter Specialist
Repair	Inverter	Replace AC contactor in inverter	As needed	Inverter Specialist
Repair	Inverter	Replace IGBT matrix in inverter	As needed	Inverter Specialist
Repair	Inverter	Replace 24VDC power supply for inverter controls	As needed	Inverter Specialist
Repair	Inverter	Replace DC contactor in inverter	As needed	Inverter Specialist
Repair	Inverter	Replace surge protection in inverter	As needed	Inverter Specialist
Repair	Inverter	Replace GFI components in inverter	As needed	Inverter Specialist
Repair	Inverter	Replace capacitors in inverter	As needed	Inverter Specialist
Repair	Inverter	Replace inductors (coils) in inverter	As needed	Inverter Specialist
Repair	Inverter	Replace fuses internal to inverter	As needed	Inverter Specialist
Repair	Inverter	Replace inverter relay/switch	As needed	Inverter Specialist
Repair	Inverter	Replace overvoltage surge suppressors for inverter	As needed	Inverter Specialist
Repair	Inverter	RE-install inverter control software	As needed	Inverter Specialist
Repair	Monitoring	Restore lost internet connection	As needed	Network/IT
Repair	PV Array	Repair or replace rack parts damaged by corrosion or physical damage	As needed	Mechanic
Repair	PV Array	Excavate and replace failed foundation element	As needed	Structural Engineer
Repair	PV module	Replace modules failing performance test after showing cracks in glazing, discoloration of metallic contacts, delamination or signs of water	As needed	Electrician
Repair	PV module	Clean, re-do connections, and re-seal junction box showing corrosion of connections.	As needed	Electrician
Repair	PV module	Replace modules showing delamination of encapsulant and back sheet	As needed	Electrician
Repair	PV module	Repair cracking of PV module back sheet	As needed	PV Module/ Array Specialist
Repair	PV module	Repair or replace damage to module frame	As needed	Specialist
Repair	Roof	Repair roof leaks	As needed	Roofer

ACTIVITY	COMPONENT	Service Description	Frequency/ Response Time	Service Provider
Repair	Roof	Re-roof (new roof)	As needed	Roofer
Repair	Roof	Roof leak repair	As needed	Roofing
Repair	Roof	roof tile repair	As needed	Roofing
Repair	Roof	Roof replacement; re-roof	As needed	Roofing
Repair	Tracker	Repair/replace tracker drive shaft	As needed	Mechanic
Repair	Tracker	Replace tracker drive bearing	As needed	Mechanic
Repair	Tracker	Replace tracker mount bearing	As needed	Mechanic
Repair	Tracker	Replace tracker motor controller	As needed	PV Module/ Array Specialist
Repair	Tracker	Replace/upgrade tracker control software	As needed	PV Module/ Array Specialist
Repair	Transformer	Replace transformer	As needed	Electrician
Repair	Transformer	Re-tap transformer	As needed	Electrician
Repair	Inverter	Replace terminal block	As needed	Journeyman Electrician
Service	Inverter	Upgrade inverter control software	5 Years	Inverter Specialist
Service	PV module	Tighten loose mounting hardware	As needed	Mechanic
	AC wiring	Locate underground AC wiring	As needed	Utilities Locator

## Federal Legislation and Executive Orders

### Energy Policy Act of 2005

EPAct 2005 defines “renewable energy” as electric energy generated from solar, wind, biomass, landfill gas, ocean (including tidal, wave, current, and thermal), geothermal, municipal solid waste, or new hydroelectric generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project.

The Act requires the Secretary of Energy to ensure that, to the extent economically feasible and technically practicable, that not less than 7.5% of the total electricity consumed by the Federal Government come from renewable energy by fiscal year 2013 and thereafter.

EPAct provides a bonus to federal agencies by allowing them to double count renewable energy if it is produced:

- On-site and used at a federal facility
- On federal lands and used by a federal facility
- On Native American land and used at a federal facility

### Energy Independence and Security Act of 2007

EISA 2007 requires new buildings and major renovations of federal buildings to reduce fossil fuel consumption relative to 2003 by:

- 65% by 2015
- 80% by 2020
- 100% by 2030

Another section of EISA 2007 requires that 30% of the hot water demand in new federal buildings (and major renovations) be met with solar hot water equipment provided it is life-cycle cost-effective.

EISA 2007 also makes it easier for federal agencies to finance renewable energy projects through energy savings performance contracts (ESPCs) through the following:

- Project funding flexibility is increased by allowing agencies to combine appropriated funds and private financing.
- Contract length limitations to less than 25 years are also restricted, as are total obligation amount limitations.

In addition, EISA 2007 expanded the definition of ESPC to address the use of excess electrical or thermal energy generated from on-site renewable sources.

### Executive Order (EO) 13423, Strengthening Federal Environmental, Energy, and Transportation Management

Executive Order 13423 reinforces previous legislative renewable goals. Specifically, the order mandates that at least half of renewable energy used by the Federal Government must come from new renewable sources (in service after January 1, 1999).

Non-electric renewable resources (e.g., solar water heating) can be used to meet this requirement, but all of the EPAct 2005 goal must be met with renewable electricity.

Consider this example: if an agency met the 7.5% by 2013 EPAct goal with wind turbines that was built before 1999, then they could use new solar water heaters to meet the E.O 13423 requirement that 3.75% be new (after 1999).

**Federal Leadership in Environmental, Energy & Economic Performance (E.O. 13514)**

Executive Order 13514 makes reduction of greenhouse gas (GHG) emissions a priority for federal agencies. The goal is to reduce GHG emissions 28% by 2020, with the baseline year of 2008. This EO also sets non-numerical targets that agencies must reach that include increasing renewable energy and renewable energy generation on agency property.

E.O. 13514 requires federal agencies to annually assess, measure, and report Scope 1, 2, and 3 GHG emissions. It allows Agencies to see what has been achieved, and offers a great opportunity to show energy use and costs reductions

**Presidential Memorandum on Federal Leadership on Energy Management**

The Presidential Memo issued in 2013 states that each agency shall ensure that the percentage of the total amount of electric energy consumed by that agency that is renewable energy is not less than:

- 10% in fiscal year 2015;
- not less than 15 percent in fiscal years 2016 and 2017;
- not less than 17.5 percent in fiscal years 2018 and 2019; and
- not less than 20 percent in fiscal year 2020 and each fiscal year thereafter.

This should be accomplished by (in order of priority):

- Installing agency-funded renewable energy on-site at federal facilities and retain renewable energy certificates;
- Contracting for energy that includes the installation of a renewable energy project on-site at a federal facility or off-site from a federal facility and the retention of renewable energy certificates for the term of the contract;
- Purchasing electricity and corresponding renewable energy certificates;
- Purchasing renewable energy certificates.

## Federal Funding Opportunities

### Congressional Appropriations

Congressional appropriations allow the government to have control over, and responsibility for the site's PV project. A site should look to round out appropriations with private sector project funding when possible through proven contract vehicles, such as ESPCs and UESCs.

Congressional appropriations can include: Capital Construction, Energy Efficiency and Renewable Energy Funding, or Operations and Maintenance Funding.

There are advantages to appropriated funding. It provides the lowest cost of funding; and there are no financing charges, overhead charges, or other associated charges. The agency also retains all of the cost savings and other environmental attributes associated with the power generated.

GSA procurement schedules include several qualified bidders that provide solar panels, inverters, and complete systems, including professional services that provide turn-key operations.

### Utility Energy Service Contracts, or UESCs

With a UESC, photovoltaic projects can be bundled with energy efficiency projects, into a long-term contract with a serving utility. In these contracts, the capital cost of PV systems can be offset by less-expensive efficiency projects and amortized over a long period of time.

Utility Energy Service Contracts are authorized by the Energy Policy Act of 1992 and the National Defense Authorization Act of 2007. Under a UESC, the serving utility arranges to provide funding to cover the costs of the project, which are then repaid over the contract term from the cost savings that are generated by the project's energy efficiency measures.

There are three types of UESCs that can fund renewable technologies: A GSA Areawide Contract, a Basic Order Agreement, and a Separate Contract. Specific Task Orders for projects can be placed under these contracts or agreements.

There are advantages of using a UESC contracting vehicle. First, the utility and agency may already have an existing relationship and the utility may have a good knowledge of the needs of the site. Second, the UESC can provide a streamlined acquisition process to contract for energy management services. And third, utilities have high credit ratings, low costs of financing, and low risks for long-term investments.

### Energy Savings Performance Contracts, or ESPCs

With ESPCs, PV can be developed as an energy conservation measure (ECM) and be included within the ESPC contract.

ESPCs are authorized by EPA, and can be an excellent way to finance photovoltaic systems. Within an ESPC, it is possible for PV technology and equipment to be "bundled" with other energy conservation measures.

The advantages to implementing a PV project as part of an ESPC is that it requires no up-front capital investment by the government; the ESPC Energy Service Company guarantees performance, and the contract can extend to a 25-year term. Long-term ESPCs allow the initial cost of the renewable energy technology to amortize over a longer period of time.

### ESPC ENABLE

ESPC ENABLE offers the same benefits as a conventional ESPC while at the same time, taking advantage of the GSA Schedule and its set of pre-qualified vendors and pre-negotiated pricing. This allows for a faster selection process so that a project can be designed and installed quickly.

Through the ESPC ENABLE program, smaller federal facilities now have the opportunity to upgrade old equipment and finance renewable systems such as photovoltaics

ESPC ENABLE now includes two new ECMs: solar photovoltaic (PV) and simple one-for-one heating, ventilation, and air conditioning (HVAC) system replacement (small building systems). Examples of equipment that may be installed under these new ECMs include:

- Solar PV,
- Ground, roof, or parking canopy mounted,
- Fixed and tracking arrays, and
- Grid-tied and off-grid.